THE BOOK OF THE DAIRY

A MANUAL OF THE

SCIENCE AND PRACTICE OF DAIRY WORK

TRANSLATED FROM THE GERMAN OF

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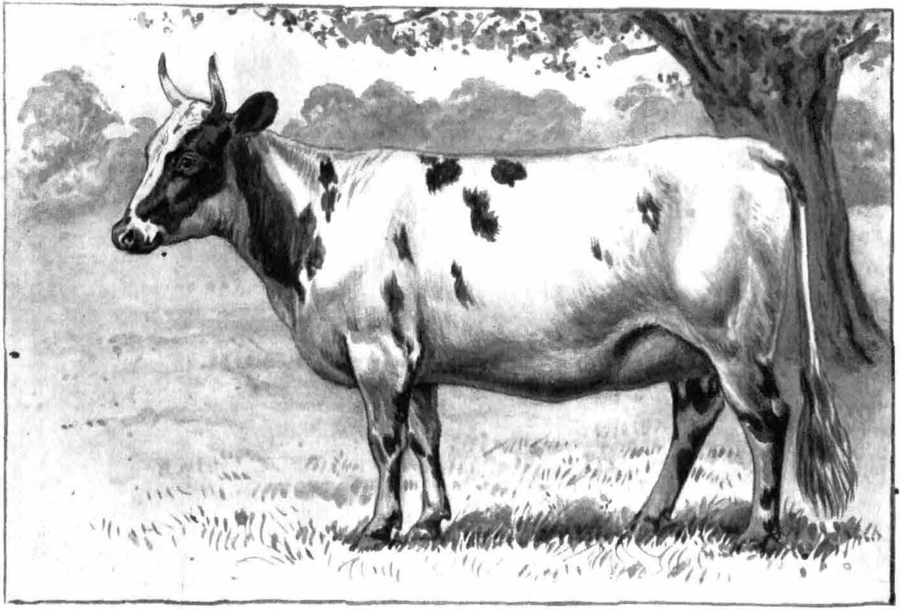

AYRSHIRE COW—"POLLY II. OF KNOCKDON".

Property of Alex. Cross, Esq., Knockdon. Winner of 1st Prize, Ayr Derby, 1890.

12 AUG 1918
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PREFACE.

The English editors have prepared this edition of Professor Fleischmann's comprehensive treatise on Dairying in the belief that in doing so they are placing in the hands of British dairy-farmers a work on the science and practice of their difficult art which will be found invaluable alike for study and for reference. They also believe that it forms a text-book specially well fitted to supplement and explain to students at our numerous Dairy Schools and Agricultural Colleges the practices of dairy management there shown in operation.

Professor Fleischmann has long enjoyed the reputation of being one of the greatest living authorities on the science and practice of dairying, and his treatise in German is familiar to all specialists as the best work on the subject. The great advances made in agricultural education in this country in recent years have been the means of calling into existence a number of excellent works in the different departments of agricultural science; but the editors believe that Professor Fleischmann's work, in an English form, supplies, in the conventional phrase, "a felt want". They trust that the addition of a considerable number of illustrations (not included in the German edition) will still further enhance its value.

The great importance of milk and other dairy products as articles of diet renders any work dealing with the subject of great interest to many others besides the dairy-farmer and

the agricultural student. It is anticipated by the translators that the work will be found of value by medical men generally, and more especially by officers of public health. They also hope that it may afford some assistance to agricultural and analytical chemists, as well as to other sanitary authorities charged with the administration of the Adulteration of Foods and Drugs Act.

The monetary value of the interest involved in dairy produce is pointed out at greater length in the Introduction. It may suffice here merely to refer to the fact, that an annual income of over £32,000,000 is estimated to be derived in this country from the sale of dairy produce, or one-sixth of the whole income of British agriculture. But enormous as this sum is, it is not all that is paid by the consumer for dairy produce, since we import it from other countries to the extent of over £20,000,000 per annum. Much of the produce represented by the £20,000,000 finds a ready market in Britain chiefly because of its high and uniform quality. There is no reason, however, why dairy produce of an equally uniform and of even a higher quality should not be manufactured at home, and thus the best position be retained in our own markets. In achieving this object everything which tends to bring about a better and more scientific knowledge of dairying may be said to help, and it is the confident expectation of the translators that the present volume will not be found altogether ineffective in promoting this purpose.

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INTRODUCTION

BY THE ENGLISH EDITORS.

It is generally allowed by those who have given attention to the progress of agriculture during the past thirty years, that perhaps the most prominent feature in its history has been the great change that has taken place in that time, in the methods and processes of dairying, and in the relative importance assigned among English-speaking peoples to dairying as a branch of agricultural science and practice. This is very clearly evidenced in all works on agricultural science and practice written prior to the present decade, in which it will generally be found that, while some pages are devoted to a description of dairy breeds of cattle, very little space is accorded to the consideration of questions relating to the management and treatment of milk, and the manufacture of butter and cheese.

The comparative neglect of dairying science, up to the present time, is probably attributable to two causes. In the first place, other branches of agriculture contributed in a much larger degree then than now to the revenue of agriculture; and in the second, dairying as an art was imperfect and empirical, and as a science had little or no existence. Up to the time when the import of foreign wheat to Britain began to assume large dimensions, the income and profits of our farmers depended in very great measure on the returns from wheat and other cereal grains. In the year 1869, for example, the total area under wheat in the United Kingdom was 3,862,202 acres, which was estimated[1] to yield 113,331,777 bushels of an average value of *6s. 0¼d.* per bushel. The total value of wheat (grain only) to the agriculture of the United Kingdom in 1869 was, therefore, more than £34,000,000 sterling. As the value of wheat, however, from that year underwent a steady decline owing to a constant increase in the foreign supply, the cultivation of this cereal was gradually abandoned by farmers as the returns became unpro-

[1] R. F. Crawford, in *Journal of the Royal Agricultural Society*, 1895.

fitable, and by the year 1893, the value of wheat in British agriculture had suffered a remarkable diminution. In that year the area under wheat in the United Kingdom had fallen to 2,215,355 acres. The yield was estimated at 67,717,160 bushels, and the price was 3s. 3½d. per bushel. The total value of the home-grown crop (grain only) in 1893 was, therefore, a little over £11,000,000 sterling, or less than a third of its value fifteen years previously. A similar, though less extreme, change had in the meantime taken place in the prices of barley, oats, and other less extensively grown grains; and other of the more important sources of farm income had undergone a similar depreciation in value. Beef, which along with grain constituted a chief source of income on the greater part of arable area in Britain, also suffered a serious fall in value in the same period. This heavy depreciation in values told not less seriously on the agriculture of Canada and of America than on that of Britain. Over a very large area, in both of these countries, the income of the farmer depended primarily on the price of wheat; and as the price has suffered year by year a steady decline, the position of the farmer has been constantly changing for the worse. Meantime, while all departments of agriculture have suffered more or less severely from the heavy fall in the value of beef, mutton, and grain, farmers whose income depended more largely on returns from dairy produce, remained, up till 1894, in a relatively prosperous condition. Not only have cheese and butter continued at high prices, but, with the steady increase of the population of the United Kingdom, as well as of America and of the Colonies, a much-increased demand has developed for articles of dairy produce, such as milk and cream, in which there has been no foreign competition of such a character as to affect prices seriously. Moreover, apart from increase of population, the practice of using milk as a regular article of diet has undergone a remarkable development during these years. This has probably originated in a more extensive knowledge of the value of milk as a food, and its intrinsic cheapness as compared with other foods; but it has also been encouraged in great measure by improvements in the supply, brought about by the development of railway enterprise, and by the guarantees of good quality which have been secured in all our large towns by the strict and careful enforcement of the measures and stringent regulations prescribed by local authorities for the construction of byres, the arrangement of dairies, and for the control of the milk supply and the

prevention of adulteration. Not a little of the increase in the consumption of milk has been due to the enterprise of dairymen and milk-sellers, and to the larger dairy companies in our cities, who, by attention to cleanliness, by prompt and convenient supply, and by the employment of the best-known means for the detection of adulteration, have succeeded in inspiring the public with confidence in the soundness and quality of the dairy produce supplied by them. Consequently, while other articles of farm produce have been steadily falling in value, milk has remained in good demand at a comparatively high level of prices, at prices that were, indeed, rising during a number of the years when the depression in arable agriculture, outside of the dairying districts, had reached its most acute and disastrous stage. The effect of these various influences, the fall in the value of other articles of agricultural produce, together with the increased consumption of dairy produce and the maintenance of high relative values alike for milk and its manufactured products, has been to raise dairying gradually into a much more important position as a branch of agriculture in Britain than it has ever before occupied.

If consideration be given merely to the value of dairy produce sold off the farms, the following estimates recently made by Mr. R. Henry Rew[1] may be quoted to show the present importance of dairying relatively to other branches of agriculture. According to these estimates, the value of the whole amount of agricultural produce of the United Kingdom sold off the farms is £197,749,477, while the value of the whole dairy produce of the United Kingdom sold off the farms is £32,493,000.

The particular forms of dairy produce from which the income is derived are estimated by Mr. Rew to be as follows:—

Description of Produce.	Quantity Sold off Farms in U.K.	Average Price.	Total Value.
Milk,	576,000,000 galls.	6¼*d.* per gall.	£15,600,000
Butter,	2,000,000 cwts.	112*s.* per cwt.	£11,760,000
Cheese,	2,000,000 „	51*s.* 4*d.* „	£5,133,000
		Total,	£32,493,000

From these estimates it appears that one-sixth of the whole income of British agriculture is derived from the sale of dairy produce. There remains, in addition, a large proportion that is consumed on the farm in the form of the milk supplied to calves,

[1] See Journal of Royal Agricultural Society, 1895.

and the milk, butter, and cheese consumed by the farmer, his household, and the labourers on the farm.

The data of total produce, however, that have been quoted comprise the returns from extensive areas of mountain land the income from which is realized, to by far the greatest extent, in the forms of mutton and wool. Hence statistics that include the returns of a large acreage of uncultivated land place dairying in a relatively less important position than would be assigned to it if the income derived from arable land only were taken into consideration. Its exact position may perhaps, therefore, be more exactly appreciated from the statistics bearing on the number and kinds of cattle in Britain. The total number of cows and heifers, in milk or in calf, in the United Kingdom in 1894, was 3,925,486, or considerably more than one-third of the total number of cattle, at that time, in the kingdom. The amount of milk yielded by this number may be estimated at 1,766,468,700 gallons. If it be assumed that one-eighth part of this yield of milk is used in rearing calves, there would remain 1,545,660,112 gallons of milk for home consumption; either in a raw condition as fresh milk, or in the manufactured forms of butter and cheese. *The science of dairying in the United Kingdom, therefore, has for its subject-matter the management, rearing, and feeding of about four millions of cows, and the production, treatment, and sale of nearly eighteen hundred million gallons of milk, and the whole processes of the manufacture of the greater part of this enormous quantity into butter and cheese.*

But great as the dairy industry is in Britain, its extent is, however, already rivalled by that of some of her colonies, and is far exceeded by that of the United States of America. The total dairy produce of the United Kingdom falls far short of the requirements of her population; while that of the United States not only supplies all that is required by her own greater population, but enables her to export large quantities both of butter and of cheese. It was about the end of the first quarter of the present century that the manufacture of dairy produce in the United States first attained to such dimensions as to exceed the needs of the home population, and to render new markets necessary. In 1826 the export of cheese to England, then recently begun, amounted only to 735,399 lbs. In 1847 it had increased to 15,000,000 lbs.; and from that date till about 1860, the total amount of cheese made in the United States was estimated to be annually about 100,000,000 lbs. By that time,

however, the system of making cheese in special factories, started in 1851, had begun to be widely adopted. In 1860 there were 23 such factories. In 1866 these had increased to 500. In 1862–63 the system that had been hitherto applied only to cheese-making was also applied to butter-making, and the first butter factory was opened. In 1866 there were 500 cheese factories, in addition to butter factories. In 1884 the number of cheese and butter factories had increased to over 4000. This rapid extension of the factory system was accompanied by a corresponding extension of dairy farming. In the twenty-two years—from 1862 to 1884—the butter production of the United States is estimated to have increased from 500,000,000 lbs. to 1,500,000,000 lbs.

About 1861 a new branch of dairy manufacture began to attract attention in the United States, viz., the manufacture of condensed milk. This branch of the dairy industry proved so prosperous that twenty years afterwards the quantity of milk treated in this fashion amounted to about 60,000,000 lbs., and the industry is still extending.

A comparison of the available statistics for the period of thirty years—from 1850 to 1880—shows, perhaps, more clearly how much more rapid was the growth of dairy farming in the United States than of even the rapidly increasing population. In 1850 the number of cows in the States was 6,392,044. In 1880 the number was 12,443,120. The butter made in 1850 amounted to 313,345,306 lbs., as compared with 806,672,071 lbs. in 1880. In 1850 the amount of cheese made was 105,535,893 lbs. In 1880 it had increased to 243,157,850 lbs. The total value of the dairy produce of the country, including milk, was estimated in 1880 to be about from 2 to 2½ times as great as it was in 1850. In 1847 the export of cheese to Britain amounted to 15,000,000 lbs. In 1894 it amounted to 75,302,864 lbs., or five times as much, in addition to about 3½ million lbs. of butter.

In Canada the progress of the dairy industry, though more recent, has been even more rapid. In 1864 the dairy produce of Canada was insufficient for the consumption of her population, and imports were made from the United States. The population in the thirty succeeding years has increased with great rapidity; yet, not only is the consumption of dairy produce fully met by home manufacture, but the exports to England in 1894 amounted to over 1000 tons of butter; while the exports of cheese amounted to over 67,000 tons, and constitute Canada by far the largest single source of

supply of the latter product to Britain. New cheese factories are now being built, and there is every prospect, therefore, that the future export will be still greater than it is at present.

In still more recent years a steady development of dairying has occurred in Australia and New Zealand, owing to the fact that the shipping of butter and cheese in good condition to this country has been proved to be practicable. The exports from Australia have proved so profitable to the producers that every year witnesses a great increase in the quantity sent over; while the home demand of these colonies for dairy produce is naturally becoming greater in proportion to the rapid increase of population. Thus, in the first six months of 1894, Australia exported to Britain 198,004 cwts. of butter, while in the first six months of 1895 the export had increased to 241,665 cwts., or a growth in one year of over 20 per cent. The total import of butter into England in 1894 was 32,000 tons more than in 1889, and nearly half of that additional quantity came from Australia. There is every probability in the near future that the Australian export of dairy produce will assume much greater dimensions; for the dairy industry in Australasia, now that an export trade to Britain has become fairly established, is advancing by leaps and bounds. A further illustration of this is found in the fact that the export of butter, which was about 3¾ millions of lbs. in 1891, had risen in 1892 to 6½ millions of lbs. In 1891–92 the number of cheese and butter factories existing was 74, while in the following year there were 109. In the Province of Victoria alone, there were in 1892–93 upwards of 400,000 milk cows, which yielded over 120 millions of gallons of milk. Of this it has been estimated that about one-third was consumed in its natural state, that about 75 millions of gallons were made into butter, and the remaining five millions of gallons into cheese. In New Zealand the energetic efforts of the Department of Agriculture have been very successfully directed to the encouragement of dairying. Only a few years ago there were no co-operative factories in existence, and, practically, there was no export trade. Cheese and butter were made only on a small scale, and almost entirely for local consumption. But in 1893 about 180 factories and creameries had become established, and in 1894 these were increased by about thirty more. The production was estimated in 1892–93 at 8,167,500 lbs. of cheese, and 6,722,303 lbs. of butter; while the exports alone in 1893 amounted to 58,147 cwts. of butter, and 46,198 cwts. of cheese. There is every

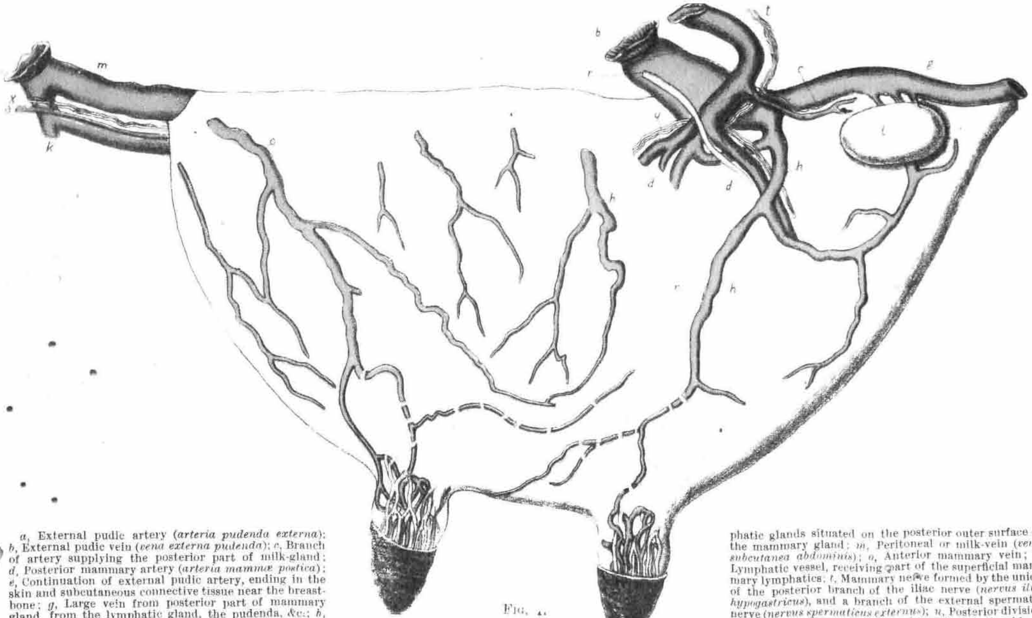
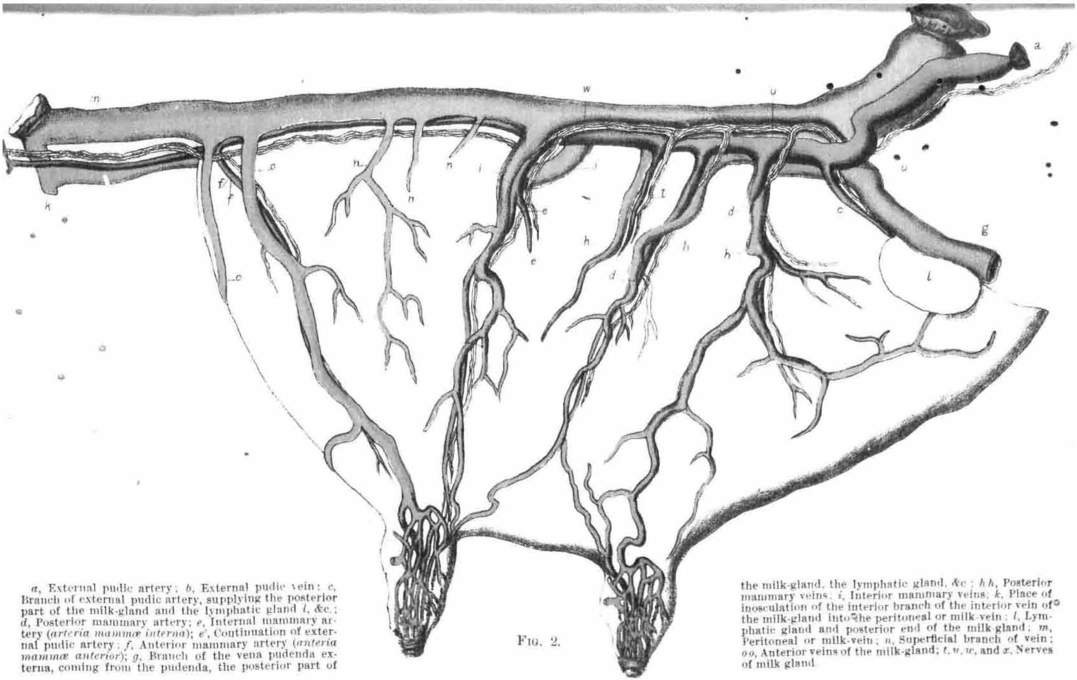


Fig. [illegible]

a, External pudic artery (*arteria pudenda externa*); *b*, External pudic vein (*vena externa pudenda*); *c*, Branch of artery supplying the posterior part of milk-gland; *d*, Posterior mammary artery (*arteria mammæ postica*); *e*, Continuation of external pudic artery, ending in the skin and subcutaneous connective tissue near the breast-bone; *g*, Large vein from posterior part of mammary gland, from the lymphatic gland, the pudenda, &c.; *h*, Posterior mammary vein (*vena mammæ postica*); *l*, Lymphatic glands situated on the posterior outer surface of the mammary gland; *m*, Peritoneal or milk-vein (*vena subcutanea abdominis*); *o*, Anterior mammary vein; *r*, Lymphatic vessel, receiving part of the superficial mammary lymphatics; *t*, Mammary nerve formed by the union of the posterior branch of the iliac nerve (*nervus ilio-hypogastricus*), and a branch of the external spermatic nerve (*nervus spermaticus externus*); *u*, Posterior division of this nerve; *x*, Continuation of *t*, ending in the skin of the navel.

THE COW'S UDDER.

Left side, with the skin removed, to show the course of the superficial arteries and veins, and the lymphatic vessels and nerves. ⅓rd natural size. (Furstenberg.)



a, External pudic artery; *b*, External pudic vein; *c*, Branch of external pudic artery, supplying the posterior part of the milk-gland and the lymphatic gland *l*, &c.; *d*, Posterior mammary artery; *e*, Internal mammary artery (*arteria mammæ interna*); *e'*, Continuation of external pudic artery; *f*, Anterior mammary artery (*anteria mammæ anterior*); *g*, Branch of the vena pudenda externa, coming from the pudenda, the posterior part of the milk-gland, the lymphatic gland, &c; *h h*, Posterior mammary veins; *i*, Interior mammary veins; *k*, Place of inosculation of the interior branch of the interior vein of the milk-gland into the peritoneal or milk-vein; *l*, Lymphatic gland and posterior end of the milk gland; *m*, Peritoneal or milk-vein; *n*, Superficial branch of vein; *o o*, Anterior veins of the milk-gland; *t*, *u*, *w*, and *x*, Nerves of milk gland.

FIG. 2.

THE COW'S UDDER.

Left side, with the superficial and deeper blood-vessels and nerves. ⅓rd natural size. (Fürstenberg.)

reason to expect that this development of dairying in New Zealand will continue to make rapid progress.

IMPORTS OF BUTTER, MARGARINE, AND CHEESE, INTO UNITED KINGDOM

FROM TRADE AND NAVIGATION RETURNS.

BUTTER.	Quantities in Cwts.			Values in £'s Sterling.		
	1892.	1893.	1894.	1892.	1893.	1894.
From Sweden, ...	228,885	267,401	266,306	£1,243,016	£1,452,099	£1,413,779
" Denmark, ...	863,532	934,787	1,102,493	4,848,735	5,278,875	5,843,954
" Germany, ...	124,233	164,985	187,755	713,859	830,706	702,960
" Holland, ...	141,838	142,811	165,157	750,314	763,897	831,951
" France, ...	542,687	468,317	424,639	3,027,648	2,679,120	2,351,839
" Canada, ...	59,571	43,160	20,887	255,652	194,924	90,071
" United States, ...	46,846	22,930	31,230	191,145	104,220	139,947
" other Countries, ...	175,417	283,083	427,596	934,821	1,449,752	2,095,918
Total, ...	2,183,009	2,327,474	2,576,063	£11,965,190	£12,753,593	£13,470,419
MARGARINE.	1892.	1893.	1894.	1892.	1893.	1894.
From Norway, ...	25,426	14,011	10,330	£70,477	£38,761	£29,369
" Holland, ...	1,196,756	1,229,737	1,045,330	3,360,707	3,416,497	2,834,804
" France, ...	56,002	41,302	29,052	192,675	160,377	115,719
" other Countries, ...	27,166	14,920	24,601	89,025	39,709	64,889
Total, ...	1,305,350	1,299,970	1,109,313	£3,712,884	£3,655,344	£3,044,781
CHEESE.	1892.	1893.	1894.	1892.	1893.	1894.
From Holland, ...	273,821	269,364	298,693	£678,573	£676,001	£760,838
" France, ...	45,605	58,346	52,965	143,208	181,763	163,322
" Canada, ...	1,038,599	1,046,704	1,142,104	2,493,625	2,575,893	2,688,946
" United States, ...	818,433	645,235	672,347	1,961,407	1,578,531	1,608,405
" other Countries, ...	56,359	57,813	97,178	139,971	148,730	245,626
Total, ...	11,139,419	11,045,986	11,876,968	£3,794,718	£3,875,647	£3,786,320

The total amount of the imports of dairy produce into Britain, with the sources from which they come, is fully shown in the table on p. 21.

It will be seen from the foregoing table that while the imports of dairy produce into Britain from the United States are still large, and while those from Canada and Australia are rapidly increasing, there are also large, and, in some cases, still increasing, supplies sent in from the several European countries which, for many years before the development of the trans-oceanic trade, formed our chief source of foreign supply.

So far as cheese and cured butter are concerned, the home manufacturer of these products has little advantage in the markets over the foreign producer, except what is afforded by any injury that may be done to the quality and flavour in the course of transit, and the costs involved in the transport of the foreign product. This, however, owing to the low rates of shipping freights that have ruled for a number of years, confers only a limited protection, and it is now generally admitted that the only hope the British dairyman has to compete successfully with the large foreign competition is by the manufacture of produce of *distinctly superior quality.* This can only be effected by giving the butter and cheese makers of this country such a training as will enable them to attain to the highest perfection in the practice of their delicate and difficult art. Unfortunately, up till quite recent years technical instruction in dairying received almost no attention in Britain. An empirical art, differing in various details of practice not only in every parish and county but even on adjacent farms, was handed down from father to son, or communicated from neighbour to neighbour in an unsystematic and incomplete form that wholly prevented any general improvement in the art of dairy manufacture. Consequently the manufactured products were very variable, and often of an inferior character and value.

While the art of dairying was thus imperfectly communicated, the science of dairying, as it is now known, had till very recently no existence. Thirty years ago there was practically no English dairy literature. Appliances for the manufacture of butter and cheese were few, and were imperfect. The principles that regulated their manufacture were not understood, and the practice was accordingly irregular and unsatisfactory. There were no dairy schools, and no recognized means of obtaining intelligent instruction in

dairying. Neither can it be said, though great improvements have taken place in recent years, that the old condition of things has yet come to an end. A number of dairy schools have now indeed been established, and have done excellent work. Systematic training in the art of butter and cheese making can be obtained without much difficulty in most parts of the country, and something is also beginning to be generally understood of the principles on which these arts should be based. A dairy literature, largely drawn from American, and indirectly from German, sources, but still to a great extent empirical, has begun to be founded; and in the practice of dairying, apart from increased knowledge or skill on the part of the operator, much advantage has been derived from the possession of modern and more suitable utensils.

But with all the progress that has been made in the past twenty years, it is undeniable that our knowledge alike of dairy practice and of dairy science is still far behind that of many of our continental competitors. This is due in great part to the position of greater importance the dairy industry holds in agricultural countries, such as Denmark and Holland, than in a country like Britain, whose wealth is derived in large measure from minerals and manufactures. In all the countries, without exception, that contribute materially to swell the imports of dairy produce into Britain, great efforts have been put forth by the respective Governments to develop and to carry to perfection manufactures on which the wealth of these countries is so largely dependent. In Britain, up till a few years ago, it was left wholly to private enterprise to provide technical instruction in dairying, and even now the amount contributed by Government to the assistance of dairy schools and colleges imparting dairying instruction amounts to not more than a few hundreds of pounds for the whole kingdom. In consequence of this, little attention has been paid in Britain to a study of the many important questions on which dairying demands the assistance of the botanist, the chemist, and above all the bacteriologist. In Denmark and Germany there are numerous and important dairy schools and agricultural colleges, largely endowed and supported by Government, in which the whole time of many able men is devoted to dairy teaching, and to the investigation of the many difficult problems that confront alike the practitioner of the dairy art and the student of dairy science.

Hence it is that till recent years English agricultural literature

has been deficient in an adequate exposition of the science and practice of dairying as now understood. Undoubtedly the most valuable information available to the English reader on this subject is to be found in the admirable Bulletins issued, from time to time, by the United States Department of Agriculture, in which the results of the more important researches in the domain of dairying science are epitomized. We are also indebted to America for some of the most recent improvements in methods and appliances, which have greatly facilitated and improved the operations of the practical art of dairying. It is to German and Scandinavian authorities, however, that we have to turn for a complete exposition of the science of dairying; and among continental authorities a first place has for many years been assigned to Professor Fleischmann.

The English editors and translators cherish the hope that in rendering Professor Fleischmann's comprehensive text-book on *The Science and Practice of Dairying* available to the English reader they may contribute something to the development of the most enlightened dairy practice. A large number of new illustrations have been introduced into the English edition; while here and there short passages have been omitted which possessed interest for German readers only.[1]

[1] The English editors desire to acknowledge their indebtedness to Dr. Paul Vieth, Director of the Hameln Milchverschaftliche Institut, and to Mr. John R. Campbell, B.Sc., lecturer on Dairying in the West of Scotland Technical College, Glasgow, for assistance in reading a portion of the work while in proof.

C. M. AIKMAN.

January, 1896. R. PATRICK WRIGHT.

THE BOOK OF THE DAIRY

CHAPTER I.

THE SECRETION, PROPERTIES, AND COMPOSITION OF MILK.

1. **Definition.**—By milk,[1] in the widest sense of the term, is understood the secretion of the special glands of the female mammal. It is a white, opaque liquid, of the character of an emulsion, with a faint odour and a slight flavour; and it is produced during a longer or shorter period after parturition. It consists chiefly of water, fat, casein, albumin, milk-sugar, and mineral salts, and is specially adapted for the sustenance of the young.

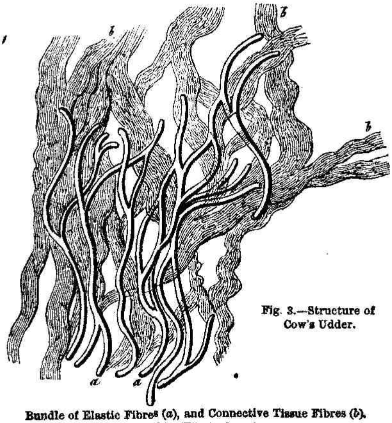


Fig. 3.—Structure of Cow's Udder.

Bundle of Elastic Fibres (a), and Connective Tissue Fibres (b). (×200.) (Fürstenberg.)

2. **The Cow's Udder.**—The particular glands in which the milk originates—the milk glands—form the most important portion of the milk-secreting udder (see plates of cow's udder, figs. 1 and 2). The cow's udder is divided into two by a strong fibrous

[1] By the term *milk* is always to be understood whole milk, and not skimmed milk.

partition, running longitudinally. Each of the halves contains a large milk-gland of a reddish-gray colour, or more correctly speaking, an accumulation of glandular structures, called the *gland-basket*. In the case of adult milk-cows, each milk-gland is from 24 to 52 centimetres (9½ to 20½ inches) in length, 16 to 31 centimetres (6¼ to 12¼ inches) in depth, and 10 to 21 centimetres

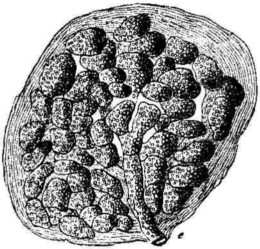


Fig. 4.—Gland-lobules. *e*, Outlet tube. (× 60.) (Fürstenberg.)

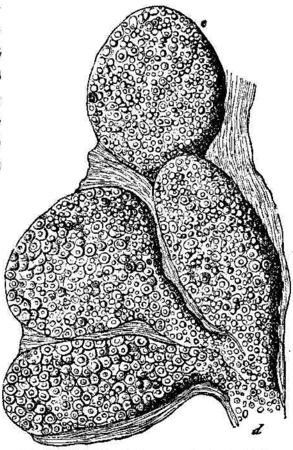


Fig. 5.—Alveoli. *d*, Common duct. (× 200.) (Fürstenberg.)

(4 to 8 inches) in breadth. They contain, embedded in a white connective tissue (fig. 3), the delicate *gland-lobules* (fig. 4), in which occur

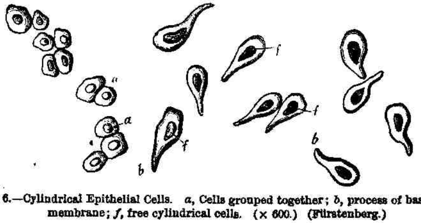


Fig. 6.—Cylindrical Epithelial Cells. *a*, Cells grouped together; *b*, process of basement membrane; *f*, free cylindrical cells. (× 600.) (Fürstenberg.)

numerous round cavities, the microscopic gland-lobules or *alveoli* (fig. 5), which are terminal or lateral dilations of numerous and extremely fine canals. When the cow is in milk the alveoli have a

length of about ·12 to ·20 millimetre (·0047 to ·0078 inch) and a breadth of ·09 to ·11 millimetre (·0035 to ·0043 inch). According to Heidenhain, the delicate tissue which surrounds the alveoli consists of a structureless membrane, the so-called *tunica propria*, to the inside of which is attached cellular tissue. The internal surface of this net-work of cells is further lined with a continuous single layer of epithelial cells (fig. 6). The diameter of these cells, on an average, is about ·04 millimetre, and their form shows extraordinary variations, according as the cow is in milk or not. In the latter case

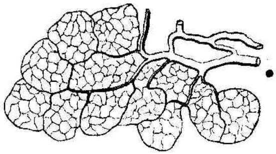


Fig. 7.—Capillaries of Mammary Glands. (× 180.) (Fürstenberg.)

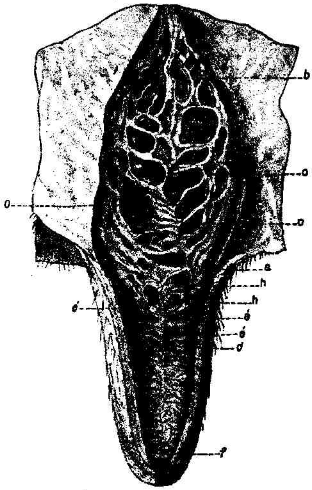


Fig. 8.—Milk-cistern and Outlet Tube of Milk-gland, laid open. Two-thirds of natural size.

a, Basis of teat; *b*, upper end of milk-cistern; *d*, lower end of same and upper end of teat; *e'*, dilatation of canal of the teat; *f*, rosette on end of lower portion of canal of teat; *h*, small, and *o*, large gland-ducts. (Fürstenberg.)

the epithelial cells are low and flat, while in the former they are swollen and protrude comparatively far into the alveolian cavity. On the outside, the membrane of the gland-lobules is surrounded by a highly

developed net-work of capillary vessels (fig. 7), in which the material for the formation of milk circulates through numerous lymph tracts, and also by means of very fine nerve fibres, which promote special physiological functions of the glands. The ductlets, of which the alveoli are the dilations, unite together among themselves in gradually ever-widening ducts—the *milk-ducts,* —and end eventually in large hollow cavities, the so-called *milk-cisterns* or *milk-reservoirs* (figs. 8–11). Four of these, which lie above the teats, are present in each udder, two on each side. The connective tissue, which encloses the lobules of the gland, and which unites them to the large closed milk-glands, is enveloped in adipose tissue, and this in turn is covered by the skin, which is interspersed with many blood-vessels. On the udder there are, as a rule, four teats (fig. 12), corresponding to the four milk-cisterns, from which milk can be drawn; while behind them frequently occur some undeveloped teats, very rarely provided with outlet tubes. The duct of the teat (figs. 13–16) is about 4 millimetres in length, and is shut at its end by means of a smooth sphincter muscle. The capacity of both milk-glands, together with that of the four milk-reservoirs, in the udder of an average cow, after milking, may be stated at about 6 to 7 cubic decimetres.[1] The internal space of the udder available for retaining milk, however, does not admit of accurate estimation, owing to the great elasticity of the surrounding tissue. The udder of a cow of ordinary milking capacity, carefully examined by us after slaughter, was found to have a

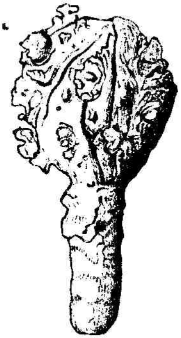


Fig. 9.—Plaster of Paris Cast of the Posterior Milk-cistern, with the Canal of the Teat of the left side, from the Udder of an Ayrshire Cow, yielding 1200 to 1300 quarts of milk yearly. Half natural size. (Fürstenberg.)

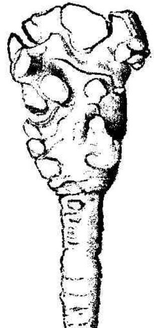


Fig. 10.—Plaster of Paris Cast of the Posterior Milk-cistern, with the Canal of the left side of the Udder of a Dutch Cow, yielding 3000 quarts of milk yearly Half natural size. (Fürstenberg.)

[1] About 10½ to 11½ pints.

total storage capacity of about 3 cubic decimetres; and for one milk-cistern, on an average, ·25 cubic decimetre.

It is unnecessary, for the purposes of this book, to enter into a detailed description of the distribution of the muscles, ligaments, adipose tissue, nerves, blood and lymph vessels, and of the skin and hair of the udder.

Fig. 11.—Plaster of Paris Cast of the Milk-cistern and Milk-ducts of the posterior half of the Milk-gland of a Dutch Cow. Natural size. (Fürstenberg.)

Four milk-glands are often spoken of, as if there were two on each side of the udder, an assumption warranted neither by the course of the milk-ducts leading to the two milk-cisterns, situated on the same side, nor by any other anatomical structure.

The physiological action which gives rise to the secretion of milk in the udder has, as its chief centre, the above described gland-lobules, which are covered inside with an epithelial cell-layer, and outside with a net-work

of capillary vessels. The practical importance of this is that the amount and quality of the milk secretion principally depends on the number of gland-lobules present in the udder, and the number and course of the vesicles distributing the blood-stream through the milk-organ. The difference in the milking qualities of different cows is primarily due, therefore, to the inherited individual characteristics.

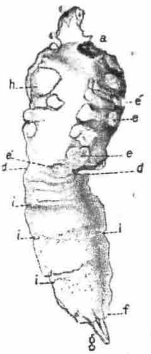


Fig. 12.—Plaster of Paris Cast of the Canal traversing the Teat and Nipple. Natural size.

a, Basis of teat; *d*, lower end of milk-cistern, and upper end of nipple; *e*, small gland-ducts; *e′*, dilatations of the canal of the teat; *f*, rosette on the lower end of canal of the teat; *g*, lower end of outlet tube of milk-gland. (Fürstenberg.)

3. **Formation of Milk.** — We conclude that, since none of the organic constituents, present in milk, is present in the blood, they are all formed in the gland-lobules from the circulating fluids, the blood and the lymph, found in the udder. But the changes which take place in this operation are little understood. Before entering into a description of them, so far as they are at present known, it should be pointed out that the milk-glands are not equally active during

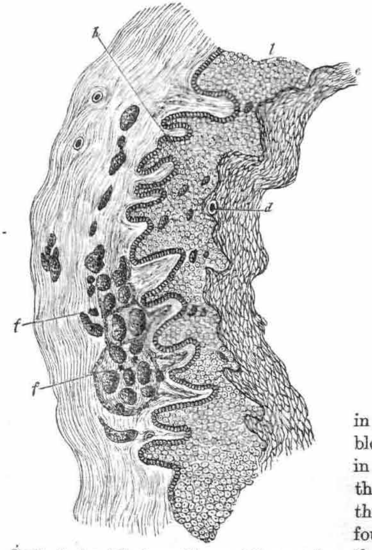


Fig. 13.—Section of Membrane of Lower and Narrow portion of the Canal of the Teat. (× 85.) (Fürstenberg.)

l, Epidermis; *e*, superficial layers of epidermis; *d*, sebaceous gland; *f*, *f*, section of bundle of muscle-fibres.

the whole lifetime of the animal. Their action is broken by alternate periods of rest. Even during the same lactation period the work of the glands does not continue at the same rate, but varies,

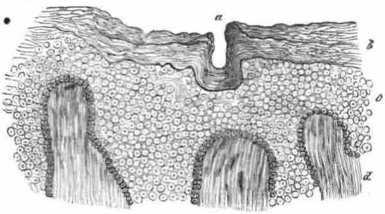


Fig. 14.—Section of Sebaceous Gland. *a*, Sebaceous gland; *b*, superficial layer of epidermis; *c*, epidermis; *d*, horny layer. (× *100*.) (*Fürstenberg*.)

on the one hand, with the period of lactation, and, on the other hand, according to the surrounding physical conditions.

According to the theory regarding the origin of milk which obtained prior to the year 1840, it was believed that the milk-glands acted as a sort of filter with a wide surface, for certain constituents of the blood, and that in milk we were dealing with a filtrant from the blood, the amount

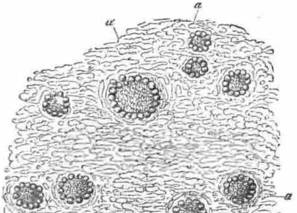


Fig. 15.—Tallow Follicle of the Nipple. (× 100.) *a*, Outlet ducts. (Fürstenberg.)

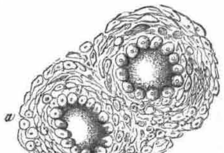


Fig. 16.—Tallow Follicle of Nipple. (× 180.) (Fürstenberg.)

and quality of which was determined solely by the amount and quality of the food. When, however, it had been proved, by chemical investigation, that not one of the organic constituents of milk occurred ready formed in the blood, but that they were all formed in the milk-gland, this theory had to be abandoned.

The labours, during the last forty years, of different physiologists, such

as Nasse, Henle, Van Bueren, Rheinhardt, H. Meyer, &c., who have carried out researches on the origin of the fat globules in milk, have demonstrated the fact, that, of all the milk constituents, fat alone, in the form of the fatty cell, is recognizable by the aid of the microscope. One of the first who submitted the gland substance to careful microscopic investigation with a view of elaborating a theory of milk production was Will of Erlangen. By means of his investigations, the theory first distinctly expressed by Virchow, regarding the origin of milk, was formulated. According to this theory, the milk-gland must be regarded, morphologically, as a kind of sebaceous gland. The separation of milk in it takes place just in the same way as that of tallow in the many-layered epithelium of the alveoli; it represents, in reality, the pathological occurrence of a fatty degeneration of the epithelium of the glands. Voit, in his work on the formation of fat in the animal body, supported this theory, which rapidly became popular. He regarded milk as a liquid cell substance—as the liquefied cell substance of the milk-glands. By the microscopical investigations of Heidenhain, Voit's conclusions were seriously called in question. According to these researches, the epithelial cells of the alveoli of the glands are only present in one layer; the colostrum bodies possess no significance for the morphology of the formation of milk; and the epithelial cells of the secreting gland are not subject to fatty degeneration. What takes place is rather that their free ends suffer degeneration, and that a renewal of the cell material takes place at the opposite end. C. Partsch also comes to the conclusion, from microscopical observations, that the formation of fat in the epithelium of the gland does not exhibit the slightest resemblance to the formation of fat in the sebaceous cell. As Partsch nowhere met with cells exhibiting fatty degeneration in the epithelial layer of the active milk-glands, and always found the fat on the points of the epithelial cells in single large drops, and the increase in the percentage of albumin in the cells accompanied by an increase in the separation of fat, he regarded it as not proven that the fat of milk is an example of retrogressive metamorphosis of the epithelial cell, but rather that it is separated through the special activity of the cell in the true sense of the word.

Subsequently Heidenhain, as well as Nissen, advanced the opinion that during the period of lactation the nuclei of the gland-cells constantly increase and successively degenerate. They are then extruded from the cells in which they have been formed, and are finally broken up in the cavities of the glandular vesicles.

This explains at the same time the method in which the nucleo-albumin, discovered by Lubavin and Hammarsten to be a constituent of milk, enters it.

Bizzozero and Vassate, by their elaborate investigations on the increase of the constituents of the growing glands of the mammals, and on their capacity for undergoing regeneration when fully developed, came to the conclusion that in milk we have not to deal with a secretion of the gland-cells. At the same time they established the fact that no evidence exists of a direct or indirect division of the epithelium of the glands during lactation, and hence that the process of milk formation is independent of the destruction of cells or of cell nuclei, as Heidenhain and Nissen had affirmed.

Rauber regards milk-fat as a decomposition product of the lymph bodies of the blood, which, as he believes, can be proved to float in the gland alveoli, and expresses the opinion that the source of the caseous matter is also to be sought for in the lymph bodies. According to him, a single principle runs through the whole scheme of nourishment of the young mammal, in so far as the lymph bodies already play an important part in the nourishment of the egg and of the embryo. With the birth of the young mammal, exit for the lymph bodies on the uterus is closed and a new exit is opened in the milk-glands, so that one and the same material is used for the nourishment of the egg and the embryo as for the nourishment of the young mammal. Through the above-mentioned researches of Heidenhain, Parstch, Bizzozero, and Vassate, the basis of Rauber's conclusions has been for the most part destroyed.

According to another series of investigations on milk formation, the origin of the different organic constituents of milk in the milk-gland is to be traced to certain maternal substances, and is carried out by certain ferments. Hoppe-Seyler, at the end of 1850, made the observation that if milk be allowed to stand exposed to the air, small quantities of fat, probably from protein matter, were formed. This formation of fat is accompanied by the absorption of oxygen and the evolution of carbonic acid gas. This observation has been confirmed by Kemmerich and Soubotin. It is a matter of dispute, however, whether this process, if it does take place, is to be regarded as a physiological one, or whether it is to be accounted for by the action of bacteria. To decide this point, Kemmerich in 1867 first introduced a method of research which consists in observing the behaviour of the secretion from the milk-gland at the temperature of the body. Supported by the results of a number of experiments, Kemmerich believed he had established the fact that during the secretion of the milk at animal heat a physiological process goes on, in which caseous matter is formed at the expense of a fermentative decomposition of albumin. This theory of Kemmerich, which in the main was also adopted by Zahn, was totally disproved in the year 1882. Schmidt-Mühlheim, by means of careful researches, proved that during the decom-

position of milk at animal heat the percentage of its albumin remains unaltered, and that its percentage of caseous matter, instead of becoming increased, is rather diminished, while the percentage of peptones present in it increases. Following the researches of Kemmerich, Danhardt endeavoured in 1870 to separate a ferment from the milk-gland of a guinea-pig. In this he succeeded, and with it he was able, by digesting in it a dilute and slightly alkaline solution of egg albumin, to obtain a body having the properties of casein. In 1833, H. Thierfelder published a work which likewise aimed at tracing the formation of the constituents of milk to maternal substances and ferments in the milk-gland and in the milk. Thierfelder believed that his researches pointed to the fact that during the digestion of the milk-gland at animal heat, a body (perhaps milk-sugar) was formed by fermentation processes, which not only possessed the reducing power, but also the properties of casein (perhaps casein itself). The researches of Hoppe-Seyler, Kemmerich, Soubotin, Zahn, Danhardt, and Thierfelder, however, which have been mentioned above, have collectively raised the important objection, that these experiments were not carried out with sufficient care, to exclude the possibility or probability of contamination with micro-organisms, through want of cleanliness in the materials experimented with.

What takes place in the formation of milk in the udder is, therefore, not as yet well understood. We do not know to what extent the constituents of the blood, the fat, the albuminoids, the carbohydrates, as well as the lymph bodies and the substance forming the epithelial cells of the alveoli of the glands, are utilized in the formation of the organic constituents of milk; and still less do we know the changes that take place in the materials which are converted into the constituents of the milk. It may be regarded as probable that milk-fat is a secretion of the epithelial cells of the gland vesicles of the udder, and that it is derived from different sources, viz., partly from the fat present in the blood, and partly from the products of the changes that take place in the animal tissue. With regard to the albuminoids, the milk-sugar, and the other constituents of milk, despite many researches, little is known. All the most recent scientific investigations, combined with numberless practical observations of cow-feeders, so far agree that the secretion of milk depends primarily on the direct influence of the greater or less activity, as well as the efficiency, of the milk-gland, and on the particular conditions under which the animal lives; and secondly, on the kind of food and condition of the blood. This

conclusion, although of a very general nature, is nevertheless of great practical importance.

4. **Properties of Milk.**—Milk, obtained under the usual conditions, is a pure white fluid, which appears completely opaque when in large quantities. In thin layers, however, it is slightly transparent. It possesses a slight smell, similar to the exhalation from the skin of the cow, and is of a mild, rich, slightly sweetish taste. It exhibits a slight amphoteric (alkaline and acid) reaction, and can be boiled without coagulating. If left standing undisturbed at the usual temperature, a collection of microscopically minute globules *of fat rises to its surface, and forms a layer of cream.* When kept standing some time longer, the milk spontaneously coagulates. Previous to coagulation the milk is in such a condition that, although at ordinary temperatures it undergoes no change, yet on boiling, or even on slightly heating it, the milk immediately changes. Even at the ordinary temperature it is coagulated on the addition of a minute quantity of a strong acid, or on the addition of carbonic acid.

On milk standing at a temperature of over 50° C., a skin is formed, consisting of coagulated albuminous matter, enclosing small quantities of the other milk constituents. As often as this skin is removed it renews itself. It is the formation of this skin on the surface of the milk that causes it when it is boiled to froth over so easily. Boiling imparts to the milk a peculiar taste and smell (cooked taste).

The chief constituents which milk contains are water, albuminous bodies (proteids), butter-fat, milk-sugar, and mineral salts. Milk has always a greater specific gravity than water. In the case of the milk of single cows, or the milk from single milkings, its specific gravity at 15° C. rarely exceeds the limits of 1·028 and 1·034, and a mixture of the milk of five or more cows, or of two or three milkings, rarely exceeds a specific gravity of 1·029 and 1·033. On an average its specific gravity may be stated at 1·0312. The specific gravity of the total solids of milk varies between 1·30 and 1·40, and that of the non-fatty solids is almost always constant, and may be stated with approximate accuracy at 1·6 at 15° C.

The opacity and colour of milk is due to the numberless fatty globules suspended in it, as well as to a portion of its albuminoids and mineral matter, which are also in a state of suspension. According to Soxhlet,

the amphoteric reaction of milk is caused by the presence in it of neutral and acid phosphates and carbonates of the alkalies. By warming the milk the alkaline reaction becomes more pronounced. Warming, however, has no influence on the acid reaction. To phenol-phthalein milk only shows an alkaline reaction after it has been neutralized with a certain amount of alkali. As a rule 100 c.c. of fresh milk require about 7 c.c. of a ¼ normal soda solution for the alkaline reaction. In order to determine the acidity in fresh milk caused by the acid phosphate, Soxhlet and Henkel treat 50 c.c. of milk with 2 c.c. of an alcoholic 2 per cent phenol-phthalein solution, and titrate with a ¼ normal soda solution. The number of c.c. required serve as an indication of the acidity. By the addition of diluted acids milk can be immediately coagulated, and, in a somewhat longer time, by means of a strong rennet solution. Dilute lactic acid and rennet change the milk into a coagulated adhesive mass. Acetic and diluted mineral acids, under similar conditions, produce flocculent coagulation. By warming milk at 50° C., or at higher temperatures, it undergoes changes which specially affect its proteids, as well as its taste and colour. Under such conditions the addition of diluted acids does not produce a lumpy coagulation, but a finely flocculent and pulpy one. The milk is also rendered much more sensitive to the action of rennet, which, under certain conditions, exerts its full coagulating influence. Milk coagulated at a temperature of 130° to 140° C. assumes the peculiar flavour of cooked milk, and becomes slightly yellowish or yellowish brown in colour. The higher milk is heated between the limits of 50° C. and 140° C., the more quickly do the above described changes take place, and the shorter is the time within which increased temperature produces the various changes. It is obvious that heating milk to 100° C. can only be accomplished in a closed vessel.

The properties of the proteids of milk are dependent, in the first place, on the nature of the chemical combinations of the mineral constituents of milk, and especially of the lime salts. If, as is actually the case, the constitution of the mineral salts of milk is changed under the influence of high temperatures, and if a portion of the soluble lime salts is converted and precipitated into an insoluble condition, it naturally follows that the condition of the proteids also undergoes change.

The peculiar smell and flavour of milk strongly heated is very probably connected with the small quantities of sulphuretted hydrogen which have been proved to be present in boiled milk. (Fresh milk, treated with tincture of guaiacum, assumes a blue colour, while boiled milk does not show this reaction.)

The change of colour which takes place on heating milk for some time at temperatures over 80° C., and which increases the higher the temperature and the longer the duration of the exposure to such temperatures,

is explained by the fact that milk-sugar undergoes incipient decomposition, producing small quantities of yellow and brown substances (lacto-caramel ?). Continuous heating affects the fineness of the state of division of the fat of the milk. The microscopically small fatty globules become partly dissolved and run together, forming large drops of fat easily visible to the naked eye. The boiling point of milk is a fraction of a degree higher, and the freezing point a fraction of a degree lower, than the boiling and freezing points of water. The maximum density point of milk is not 4·08° C., as is the case with water, but − ·3° C. Possibly these conditions vary with the percentage of solids in the milk, especially of fat, but no experiments have been made on this point. The behaviour of milk under the influence of the electric current also requires investigation. The question of how far electricity might be beneficially applied in dairying still awaits investigation.

The coefficient of expansion of milk increases with the temperature, as well as with the percentage of total solids, and, between the temperatures of 5° and 15° C., is undoubtedly greater than that of water. It follows from this that milk loses more and more of its limpidity as the temperature is reduced, and at temperatures below 10° C. it assumes a slightly viscous condition, and maintains this viscosity on its surface. According to experiments by the author, the variation in the volume of ordinary cows' milk (of a specific gravity 1·0315 at 15° C.) at different temperatures is as follows:—

1,000,000	volumes at	0° C.
1,000,030	,,	1° C.
1,000,391	,,	4° C.
1,001,273	,,	10° C.
1,002,134	,,	15° C.
1,003,800	,,	20° C.
1,006,414	,,	30° C.
1,014,277	,,	50° C.
1,019,243	,,	60° C.

The absorptive capacity of milk for heat (latent heat) is not a constant quantity, but depends, according to experiments carried out by the author in 1874, on the quantity of total solids. For milk of ordinary chemical composition it may be stated at ·847, water being taken as 1·000.

When exposed to the action of frost the larger portion of the milk is frozen, a small portion only remaining liquid. The portion remaining liquid is richer in solid matter than the portion frozen.

When milk is subjected to dialysis only a portion of the mineral matter and the milk-sugar diffuse through, and possibly also a trace of nitrogenous matter.

If a candle light be looked at through a thin layer of milk, the flame usually appears yellow, but occasionally it appears of a reddish colour. *The thickness of the milk layer with which this takes place is dependent upon the percentage of fat the milk contains*, but is not directly proportional to its amount, as it is also dependent upon the size of the fatty globules present. The same quantity of fat retards more light when it is in the form of very small globules, than when it is in the form of larger globules. It is for this reason that the determination of fat by the so-called optical method is so very unreliable.

According to Jörgensen, the refractive index of milk serum lies between 1·3470 and 1·3515, and that of curd, coagulated by rennet, between 1·3433 and 1·3465.

It may be taken for granted, that the suspended matters of milk—the fat, the nitrogenous substances, and the phosphate of lime—have the same effect upon the chemical balance and on the hydrometer as if they were in solution, although this does not necessarily follow as a self-evident fact. Mach has shown that very finely divided bodies suspended in liquids only exert their weight on the balance and areometer when they are either at rest, or are moving with a regular speed. That these conditions are fulfilled by the substances in suspension in milk is proved by the fact that *tests of the specific gravity of milk conducted in a most careful way, both with the balance and with the hydrometer, give constant and perfectly concurrent results.*

It is noteworthy that milk, rich in fat, despite this richness in a constituent of low specific gravity, does not generally exhibit a low specific gravity, nor milk poor in fat, a high specific gravity. This is owing to the fact that milk rich in fat is also rich in the other solid constituents, and milk poor in fat is also poor in the other constituents. The specific gravity of milk is always exactly proportional to the percentage of the non-fatty solids. W. Thorner has investigated the resistance which milk offers to the electric current, and has found that *the resistance of pure milk is not an absolutely constant quantity.* It is more or less increased by the addition of water, diminishes with increasing acidity of the milk, and is independent of the amount of fat it contains.

5. The Nitrogenous Matter in Milk.—This forms from 2·5 per cent to 4·2 per cent—on an average 3·5 per cent—of the contents of milk, and consists of substances of the nature of protein—the so-called albuminoids. Duclaux's theory, that there is only one albuminoid in milk, is not consistent with the properties exhibited by it. It is highly probable that milk contains three albuminoids—*casein, lactalbumin,* and *globulin*—the casein being very much in

excess of the others, and forming about 80 per cent of the total nitrogenous compounds. Casein contains nuclein, a substance which is not found in albumin, and which is characteristic of the cell nucleus. It is rich in phosphorus, and strongly resists the action of pepsin solutions. While it has the properties of an acid it is also able to form saline compounds with bases, and is insoluble in water. On the other hand, its compound with lime (calcium oxide)—in which form it is present in milk—is soluble in water, or, more correctly speaking, forms with water a bulky colloidal substance, which, when milk is filtered through porous clay cells, does not pass into the filtrate, and is not absorbed when milk is passed through porous clay plates (Lehmann plates). The other albuminoids present in milk are in true solution, *i.e.* when milk is filtered through porous clay cells they pass into the filtrate. In order to distinguish the casein present in milk, which is in combination with lime, from pure casein, it is called the caseous matter of milk. A very small portion of this caseous matter, at most from ·5 to 1 per cent, is removed from the milk in the separators by centrifugal force, and forms the chief constituent of the separator residue. When milk spontaneously becomes sour, or is coagulated by the addition of acids, the lime which it contains is separated from the caseous matter, and the insoluble casein coagulates in the form of a clot. Under the action of rennet, casein is converted into paracasein and curd protein. The former, provided there is a sufficiency of lime salts present to effect precipitation, is precipitated, and the latter remains in solution. In both cases the clots thus formed enclose mechanically the particles of fat present in the milk. When milk is coagulated by rennet, or by the addition of substances which act as dehydrating agents, as, for example, neutral salts or alcohol, the precipitate thrown down contains not merely the fat, but also the calcium phosphate in suspension in the milk. If, on the other hand, milk is coagulated by acids, or is allowed to become spontaneously sour, the greater portion of the suspended mineral salts is left in solution, and the coagulated casein contains only minute quantities of calcium phosphate.

The extent to which the caseous matter is precipitated varies in the case of milk derived from different sources. Even in the same sample of milk the caseous matter is not coagulated to the same extent, even although the conditions under which coagulation takes place are similar. As a rule, the coagulation obtained is greatest immediately after milking, and diminishes with the lapse of time.

It is found that in milk standing for a time after milking, a coagulation of the caseous matter takes place. The result of this is, that the specific gravity of perfectly fresh milk, determined by means of the hydrometer at 15° C., will always be found to be higher, to the extent of from ·5 to one thousandth than in the same milk when rapidly cooled or allowed to stand for some hours. For this reason special precautions ought to be taken in testing the specific gravity of milk with the hydrometer. The extent to which the precipitation of the caseous matter takes place depends on the temperature—with a rising temperature it is increased, while with a falling temperature it is diminished. For this reason, in the raising of cream, equable low temperatures in the milk are not favourable, because with low temperatures the fatty globules meet with increased resistance in rising to the top.

Among the more important early researches on the nature of the albuminoids and caseous matter of milk may be mentioned those of Scherer, Nasse, Schützenberger, Knop, and others. The theory first advanced by Scherer in 1841, which was held for thirty years, that the caseous matter is in the form of potassium albuminate, has now been completely controverted. The view which has been held on the subject of the nitrogenous matter in milk, since 1875, is based on the reactions exhibited by milk with certain reagents.

If milk be precipitated, at the ordinary temperature, by dilute vinegar, the larger portion of the nitrogenous matter is thrown down as a precipitate. If the filtrate from this precipitate be heated, a second precipitate is formed. The filtrate from this precipitate again gives a third precipitate with alcohol; and by treating the filtrate from this last precipitate with Millon's reagent, a fourth precipitate is obtained. It was consequently believed that each one of these precipitates represented a separate albuminoid, and these were distinguished as casein, albumin, albuminose (Bouchardat and Quevenne), and lactoprotein (Millon and Commaille).

But it may be pointed out, that the behaviour of the milk, as above described, admits equally of the view which regards the nitrogenous substance of the milk as consisting of one substance only. It merely practically proves that the nitrogenous substance of the milk, at ordinary temperatures, is only partially precipitated by vinegar, more completely by vinegar at boiling temperature, and still more perfectly by alcohol, and that it is completely precipitated by certain salts of the heavy metals. No necessity exists, for inferring, on these grounds, the existence of four separate albuminoid bodies, any more than for supposing, for example, without further evidence, that there are four different kinds of lime,

because lime is more or less perfectly precipitated from its solutions, by different reagents, under different circumstances.

An important advance in our knowledge of the nature of the nitrogenous matter of milk was made by the comprehensive and thorough researches of O. Hammarsten of Upsala. These researches render it highly probable, that the large amount of albuminous matter which is precipitated, at ordinary temperatures, by acetic acid, and which has long been known as casein, is a characteristic albuminoid, with distinctive properties, and that in addition to this body there are two other albuminoids present in milk, viz., *lactalbumin*, and, in very small quantities, *globulin*. Hammarsten considers casein a nucleo-albumin—a body in which nuclein is in complex chemical combination with albumin. According to him, the chemical composition of pure casein is as follows:—

Carbon, ...	52·95
Hydrogen, ...	7·05
Nitrogen, ...	15·65
Oxygen, ...	22·78
Sulphur, ...	0·72
Phosphorus, ...	0·85
	100·00

His lactalbumin contains neither nuclein nor phosphorus, and has 1·7 per cent of sulphur—that is, about as much as pure egg-albumin, which contains 1·6 per cent. The lactoprotein of Millon and Commaille, Hammarsten considers to be made up of a mixture of imperfectly precipitated casein, and small quantities of albumin, partially converted into syntonin and peptones. He further holds that the acid character of casein is due to the fact that the condition of the casein in milk depends on the calcium phosphate, and that the coagulation of milk cannot take place without calcium phosphate. What the nature of the relationship existing between the casein and the calcium phosphate is, he does not state. Eugling's assertion, that the casein is always present in milk in chemical combination with normal calcium phosphate, rests on observations which, on examination, do not appear to be reliable.

According to Danilewski and Radenhausen, milk contains no fewer than seven different nitrogenous bodies, which belong to the albuminoid group, or are nearly related to it. Their highly artificial theory that casein is a mixture of caseo-albumin and caseo-protoalbumin bodies lacks sufficient proof.

More recently Duclaux has again revived the original theory, that the albumin and the remaining nitrogenous substances are not really

different, and that in milk there is only one albuminoid, viz., casein. According to him, the changes which the milk undergoes, as above described, are to be accounted for by the fact that casein in solution, and when precipitated, acts differently. Lactoprotein and albumin are, as Duclaux assumes, nothing else than casein in conditions more or less soluble in water.

Among the most recent investigations on the nature of the nitrogenous substance of milk, undoubtedly the most valuable work is that by Söldner, entitled, *The Salts of Milk and their Relations to the Conditions of Casein.*

Söldner opposes to Hammarsten's vaguely expressed theory that casein and calcium phosphate are present in the milk in solution, the exact and well authenticated theory that the caseous substance of the milk must be regarded as consisting of a neutral calcium compound of casein, and that the action of the rennet does not depend on the presence of calcium phosphate, but chiefly on the presence of a soluble lime salt. Further on, in the Chapter on the Preparation of Casein, we will have an opportunity of again referring to Söldner's work.

Within the limits of 0° to 100° C., the amount of acid or neutral salts which is necessary to effect the precipitation of casein, decreases with an increase of temperature; while within the limits of 0° and 42° C., the length of time which elapses before the spontaneous coagulation of the milk takes place also decreases with the increase of temperature. Normal sodium carbonate, caustic alkalies, normal sodium phosphate, and other salts, which effect the precipitation of solutions of calcium phosphate, although they are themselves solvents of casein, yet in the process of coagulation cause its precipitation. This is effected by the fat and casein becoming mechanically entangled with the precipitated tricalcium phosphate, and carried down with it. The addition to milk of a small quantity of a caustic alkali, or of a carbonate of the alkalies, diminishes its opacity.

Solutions of caseous matter, on standing at temperatures of over 50° C., become covered with a skin, and when heated in close air-tight vessels to 130° to 140° C. become coagulated, and exhibit greater lævo-rotatory properties than solutions of albumin; and are precipitated by dilute acids, by most of the salts of the heavy metals, by alcohol, and by rennet, provided the dissolved calcium salts necessary for this purpose are present. The heat equivalent of casein, according to Stohmann's investigations, amounts to 5715 calories per gram of substance. Schübler gives the specific gravity of fresh casein as 1·100, and of boiled casein as 1·259. According to the investigations of the author, the pure nitrogenous matter of milk at 15° C. has a specific gravity of 1·486.

Of equal interest, both from a theoretical and practical point of view, is the relationship which exists between the nitrogenous constituents of

milk on the one hand, and the mineral salts on the other. All influences *that are able to change the constitution of the salts of milk, such as the prolonged action of high temperature, the evolution of carbonic acid from* milk fresh from the cow, the formation of lactic acid through fermentation, the diseases of cows, their feeding, the time since calving, the age of the cow, the boiling of milk, &c., also exercise an influence on the nature and properties of the nitrogenous substances, especially on the caseous matter. They alter to a slight extent the specific gravity of the milk, cause the rising of the cream to take place either more rapidly or more slowly, and make the milk more susceptible, less susceptible, or entirely unsusceptible, to the action of rennet. They favour or retard its coagulation by acids, and influence the nature of the curd produced by the action of rennet or acids.

6. **Milk-fat (Butter-fat).**—Milk-fat is present in milk in a very fine state of division, viz., in the form of innumerable little drops or globules of varying size, which are all of them invisible to the naked eye. In the milk of cows the diameter of the smallest and the largest of these globules is respectively ·0016 mm. and ·01 mm., so that the former is almost 6·25 times as small as the latter (fig. 17). The globules vary in size between these limits, and are present in varying proportions. It appears probable that the number of the different-sized globules is in inverse ratio to their size, or, what is the same thing, the weight of the sum of all the globules of the same size is equal for the entire number of different sizes. At anyrate, the microscopical examination of milk shows that the smaller the globules the more numerous they are.

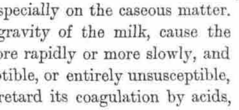


Fig. 17.—Milk Globules. (×300.) (Fürstenberg.) *a*, Small ones found in milk after separation; *b*, large ones found in cream.

Under the ordinary conditions which prevail in Germany, the percentage of fat in cows' milk, with very few exceptions, varies between 2·5 and 4·5, and may be stated, on an average, at 3·4. For the north and north-east of Germany, the average may be stated at 3·25.[1]

[1] The average of all complete American analyses of milk made up, 1891, is 4% of fat, the limits being from 2 to 8%; while the average of over one hundred and twenty thousand samples of English milk, as analysed by Dr. Vieth, is 4·1% of fat. (See Aikman's *Milk: its Nature and Composition* (A. & C. Black), p. 11.)—*English Editors.*

The fat globules are not surrounded with a membranous envelope. Owing to the action of molecular force, the little globules are surrounded by a thin watery covering of serum, and act very much as if they were actually surrounded by a membrane. The influence of the molecular force, manifested in all emulsions, explains why the fat globules in a layer of cream, at ordinary temperatures, do not cohere, and explains why the application of a not inconsiderable force in churning is required to bring them together, and why they offer some resistance to the solvent action of ether.

As the specific gravity of fat is less than that of milk serum, all the fat globules are under the influence of a force which compels them to ascend to the surface. It has been calculated that this influence acts very rapidly. Thus by keeping a layer of milk 10 to 20 cc. in depth for a day and a night, at rest and at ordinary temperature, about four-fifths of its total fat comes to the surface. The smallest globules containing the rest of the fat do not experience a motion of their own, because their tendency to rise is no longer sufficient to overcome the opposition offered by the friction of the coagulated casein in which they are enveloped.

The use of separators has done much to increase the yield of fat. By their aid all the fat may be extracted to within 5 per cent from the milk or cream treated. It is in the highest degree probable that the fat globules, both in milk and cream, are present in a liquid form at ordinary temperatures, and that they are only converted into a solid form by the action of churning.

The superior digestibility of milk-fat, when partaken of in the form of milk, cream or butter, may be traced to the extreme minuteness of its state of division.

The composition of the fat of milk does not resemble that of fat obtained from other sources. It is of a much less simple chemical nature than that of other fats. Butter is distinguished from them by its more agreeable taste. The soft condition of butter fat at ordinary temperatures renders it in a special degree suitable for spreading on bread. As is the case with other organic substances of complex composition, it is readily liable to change, is less easily preserved than the other edible fats, and quickly loses its fine flavour under unfavourable circumstances. These special properties of milk-fat render butter the most valued and the most highly prized of all fats.

The fat globules were first discovered and described in 1697 by A. Von Leeuwenhoeck. The number of these fat globules in a drop of milk varies; but it is almost impossible to count them. A conception of the fineness of the state of division of the fat in milk is best obtained, so far as it is possible to measure it, by means of a simple calculation, from which we obtain the following results, in the case of a sample of milk containing 4 per cent of fat (taking the specific gravity of pure milk-fat as ·924 at 17·5° C.):—

	Diameter, in ·01 mm.	Diameter in ·0016 mm.
The weight of a globule, -	·000,000,483,8 mg.	·000,000,002,0 mg.
The number of globules in 1 kilo. (approximately), -	80,000 millions,	20 billions.
The surface area of the globules in 1 kilo. of milk is approximately, - -	25 square metres,	157 square metres.

If the diameter of the largest globule be 6·25 times that of the smallest, then its weight will be 244 times that of the smallest.

The impetus γ and ϕ which a globule receives through its weight and centrifugal force may be stated as follows:—

$$\gamma = a . g \left(\frac{\delta}{\delta'} - 1\right) \text{ and } \phi = a' \left(\frac{\delta}{\delta'} - 1\right) \cdot \left(\frac{2 . \pi}{60}\right)^2 \cdot r,\ u^2,$$

in which a, and a', indicate the respective coefficients of resistance, δ, and δ', the viscosity of the milk serum and milk fat, g the acceleration due to specific gravity, and π the Ludolph number, r the radius vector, and u the number indicating the circumference of the globule. The movement of the fat globules in milk towards the cream layer in the ordinary rising of cream, as also in the separation of cream by centrifugal force, is obviously not an accelerated one, but is uniform throughout. The other animal fats, which, in addition to milk-fat, act as foods, are chiefly made up of stearin, palmitin, and olein; while milk-fat only contains, on an average, about 91 to 92 per cent of these neutral fats. The remaining 8 to 9 per cent probably consists of seven other neutral fats, among which butyrin and capronin predominate Other five, viz. caprylin, caprinin, laurin, myristin, and butin, are present in very minute quantities, some of them in the most minute traces.

If pure butter-fat be saponified, and the butter so obtained be carefully decomposed with sulphuric acid, as in the Hehner and Angell process, the separation of the characteristic group of non-volatile and insoluble fatty acids (stearic, palmitic, oleic, myristic, and butic acids), from the remaining volatile and soluble fatty acids, can be easily effected, and their exact percentage determined. It is, however, impossible to estimate, even approximately, the percentage of the individual fats of either the non-volatile or

volatile groups. The individual members of both groups exhibit such slight differences in their chemical behaviour and distinctive properties, that as yet it has been found impossible to separate them from one another, or to determine their composition. On this account the proportion of stearin, palmitin, and olein in milk-fat, generally stated in the literature of the subject, is practically unreliable. At the most, by determining the so-called iodine coefficient of milk-fat, which is proportional to the amount of olein it contains, it can be ascertained which of two given samples of milk-fat contains most olein. For the approximate determination of the amount of the individual volatile fatty acids in milk-fat, Duclaux has devised an ingenious method of determination. By this method the fatty acids are reckoned as triglycerides, and the probable average composition of milk-fat is calculated approximately as follows:—

Palmitin, stearin, olein, and traces of myristin and butin,	91·50
Butyrin, ...	4·20
Capronin, ...	2·50
Caprylin, caprinin, and traces of laurin, ...	1·80
	100·00

The percentage of insoluble and soluble fatty acids varies according to the length of time after lactation, the amount of the soluble fatty acids gradually diminishing, and that of the insoluble acids increasing, with the increase of the duration of this period. To a certain extent the amount is influenced by the individuality of the animal, and by the breed, probably also by the age of the cow; but the influence of feeding has not yet been proved with certainty. According to Adolf Mayer the percentage of the volatile fatty acids in milk-fat is distinctly increased by feeding with fresh meadow hay, and is diminished by feeding with straw and poppy-cake. The percentage of olein in milk-fat appears to increase with the lapse of time after lactation. Butter-fat, containing a small percentage of volatile fatty acids, contains, as a rule, a correspondingly larger percentage of non-volatile fatty acids.

Lecithin, a substance containing nitrogen and phosphorus, may be mentioned as a characteristic constituent of milk-fat. It is further to be noticed with regard to the chemical composition of milk-fat, that it contains less carbon than other kinds of fat. Milk-fat, freshly separated from cows' milk, is, at ordinary temperatures, a soft yellowish mass, which soon assumes a granular structure, and possesses a mild taste and very slight odour. If melted butter-fat be allowed to cool gradually, it occasionally occurs that a separation of the mass into two parts takes place, viz. a solid portion, and a portion called butter-oil, which remains liquid at ordinary temperatures. Milk-fat melts usually between 31° C. and 36° C.; occasion-

ally at not less than 41° C. to 42° C. In the case of most other fats the melting-point is higher. The majority of the insoluble fatty acids which make up milk-fat (palmitic, stearic, and oleic acids) melt at temperatures between 38° C. and 39° C., or, according to Adolf Mayer's researches, between 41° C. and 44° C., and become solid between 35° C. and 38° C. The solidifying point of milk-fat lies, as a rule, between 19° C. and 24° C. It may, however, vary between 27° C. and 12° C. At the moment of solidification only a slight rise in temperature takes place, which proves that the latent heat of milk-fat is very slight. The consistence and colour of milk-fat depend on the influence of feeding, and vary according to the lapse of time after the lactation period. They appear also to be dependent on the age and individuality of the animal. The melting point of milk-fat is said to be lowered by feeding with easily digestible carbohydrates, and raised by feeding with fodders poor in sugar, such as straw and oil-cakes.

The specific gravity of milk-fat in air at 15° C. (distilled water taken at the same temperature = 1) is, on an average, ·930717; and in vacuum (water taken at 4° C. as 1) it is, on an average, ·93002. At the boiling point of water, and at a barometric pressure of 760 mm., reduced to 0° C., it varies between ·8650 and ·8685. Most of the other fats, at the boiling point of water, possess a specific gravity of less than ·8610. According to M. Schrodt, the refraction exponent of milk-fat is only subject to small variations, and is neither affected by the feeding of the cow, nor by the lactation period, and is, at 22° C., on an average, 1·4590. With the diminution of the percentage of the fatty acids it appears to increase. If pure milk-fat be preserved from the action of air for some time, it becomes rancid, that is, decomposition sets in, and small quantities of volatile fatty acids, and particularly butyric acid, are set free. Free exposure to air and sunshine hastens the decomposition. Under such conditions volatile fatty acids, directly derived from the glycerides of butter-fat, are also set free, and other fatty acids, of which formic acid is probably one, are formed, oxygen being absorbed from the air. Milk-fat, in this process of decomposition, possesses not merely a rancid and strongly tallowish smell and taste, but also assumes a white colour. Certain moulds, when the milk becomes infected with them, produce decomposition, which is accompanied by a gradual diminution of the volatile fatty acids of the milk-fat. In this process butyrin shows itself to be less easily decomposed than capronin, and the latter less easily decomposed than the neutral fats of the essential fatty acids.

Although the hypothesis that the larger and the smaller of the fatty globules of milk contain different kinds of fat, has not, so far, been conclusively proved, it has become more and more probable. The fat of the

larger globules appears to be finer in flavour, and to possess a more oily appearance.

Bouchardat and Quevenne drew attention, as early as 1857, to the fact that the average size of the fatty globules in human milk was different from that found in the milk of cows or of sheep. It is probable that the average size of the fatty globules of cows' milk, in the same cow, is not at all times, and under all conditions, the same; and that in the case of different cows, perhaps also in the case of different breeds of cows, even under similar circumstances, the size varies. On this subject we know as yet very little. The methods, according to which the numbers and the determination of the average size of the fatty globules have been made, are the same as have been applied for the purpose of counting the number of yeast cells, blood corpuscles, &c., and consist of utilizing very fine capillary tubes of glass.

Milk-fat is soluble in ethyl-ether, chloroform, carbon bisulphide, benzine, &c. The common solvent is ethyl-ether.

7. **Milk-sugar.**—Milk-sugar occurs in solution in the milk of all mammals, but does not elsewhere occur in nature. It is a carbohydrate, and is one of the sugars capable of being converted directly into alcohol by means of fermentation. In German milk the percentage of milk-sugar ranges between 3 and 6 per cent, and is on an average 4·6 per cent.[1]

In a state of solution, as it is in milk, the milk-sugar quickly and easily undergoes decomposition, and is converted into lactic acid. This is effected by a large number of different kinds of bacteria, the so-called lactic bacteria. The transformation of milk-sugar into lactic acid may, or may not, be accompanied by the formation of small quantities of carbonic acid, with or without alcohol. As the bacteria which give rise to the formation of lactic acid are to be invariably found more or less abundantly on the cow's udder or in the byre, in the dairies or in the vessels containing the milk, and have therefore easy access to the milk, it follows that milk, on keeping, becomes sooner or later subject to lactic fermentation. As soon as a sufficient quantity of lactic acid is produced, milk sours and becomes unsuitable for its chief uses, both in the house and the dairy. In milk which has become spontaneously sour, several kinds of lactic bacteria may be identified. With regard to one kind of bacteria, viz. the *bacillus acidi lactici, I.*

[1] The same holds good for English milk. American milk ranges from 4 to 5·5, with an average of 4·95. (See Aikman's *Milk: its Nature and Composition*, p. 11.)—*English Editors.*

Hueppe, Hueppe has shown that its development ceases below temperatures of *10° C.*, is very feeble at *12° C.*, increases very much above 15° C., and goes on briskly at temperatures between 35° C. and 42° C. When the temperature is raised above 42° C. its development diminishes, until, at between 45·3° C. to 45·5° C., it entirely ceases. Practical experience has shown that with regard to *other bacteria effecting lactic fermentation, rapid development* only begins at a temperature above 15° C. 15° C., therefore, may be regarded as the temperature below which warm milk should be cooled as quickly as possible if it is to be kept, and above which cold milk should not be warmed if its keeping quality is not to be impaired. The reason, therefore, why milk at 16° C. to 20° C. will keep, even under the most favourable conditions, for only some 50 hours, and why it becomes necessary to have recourse to costly and inconvenient preservative measures, is due almost entirely to the milk-sugar present in the milk. In practice the only admissible physical means for the prevention of premature souring in milk is the cooling of the milk below 10° C., or heating it above 50° C. The treatment of milk with chemicals (sodium carbonate, boracic acid, salicylic acid, hydrogen peroxide, &c.) for effecting this purpose is to be absolutely condemned.

Milk-sugar (*lactine, lactose*, $C_{12}H_{22}O_{11} . H_2O$) was first discovered as a constituent of milk in 1619 by Bartoletti. It crystallizes in deep rhombic prisms, of a white transparent colour, and contains 5 per cent of water of crystallization. It is comparatively hard, and is insoluble in absolute alcohol and ether. It is soluble in 2½ parts of boiling water, and 6 parts of cold water. In concentrated solutions it presents a viscous appearance, and exhibits a tendency to form supersaturated solutions. It is only slightly sweet to the taste. Its specific gravity, compared with water at 4° C., is 1·545, and its elementary composition is as follows:—

Carbon, ...	40·00
Hydrogen, ...	6·11
Oxygen, ...	48·89
Water of crystallization.	5·00
	100·00

Crystallized milk-sugar does not part with its water of crystallization when heated to 100° C. On being heated for some time to a temperature of from 100° to 130° C., it becomes slightly brown in parts, and begins to decompose: a slight quantity of oxygen is absorbed, and a corresponding

amount of carbonic acid is given off. At 130° C. further decomposition takes place, its water of crystallization is given off and galactose is formed. This brown coloration becomes more pronounced as the temperature rises. Lactocaramel, which is dark brown in colour, begins to be formed at 175° C., and is accompanied by the development of a characteristic smell. Grape-sugar is perhaps also formed. In milk this decomposition begins when the temperature rises above 70° C., and is rendered apparent by the slightly brown coloration (more or less pronounced according to the length of time the milk is heated) which the milk assumes. Three different forms of anhydrous milk-sugar are known. The optical behaviour of solutions of milk-sugar under the polariscope is complicated, since they exhibit bi-rotation and half rotation.

It is not as yet certain whether milk-sugar is rendered anhydrous, or retains part or the whole of its water of crystallization, when it is heated in the process for the determination of its total solids; or whether, indeed, under the varying circumstances under which such desiccation may take place, it behaves always in the same manner. It would seem probable that this is not the case, since, as is well known, the total solids in milk do not admit of such accurate determination as is the case with the milk-fat.

Solutions of milk-sugar, at ordinary temperatures, reduce alkaline copper solutions. Treated with yeast or dilute sulphuric acid, galactose and grape-sugar are formed. Galactose, an isomere of grape-sugar, and a direct product of the fermentation of the sugars, can be obtained in small white plate-shaped crystals. If milk-sugar be warmed with nitric acid, mucic and oxalic acids are formed, and also saccharic and tartaric acids. With bases milk-sugar forms saccharates. Galactose yields, when boiled with nitric acid, double the amount of mucous acid yielded by milk-sugar when treated in the same way. When heated with hydrochloric acid it yields lævulin acid. When heated with chalk, milk-sugar yields isosaccharine and metasaccharine. Although a molecule of milk-sugar and a molecule of water contain the elements of four molecules of lactic acid ($C_3 H_6 O_3$), in the case of ordinary lactic fermentation, decomposition never takes place so completely and exactly that the milk-sugar is entirely converted into lactic acid. Small quantities of a number of other products in addition to lactic acid are formed, possibly from the milk-sugar and possibly also from the nitrogenous matter of the milk. The most extensive and thorough of recent researches on lactic fermentation have been carried out by Hueppe. His pupil Scholl has isolated and given an exact description of ten different kinds of bacteria. The facultative lactic bacteria are not of immediate importance since they are rarely found in milk. The same applies to the few moulds (yeast) which

have the power of converting milk-sugar into lactic acid and alcohol. By the gradual formation of free lactic acid in the process of lactic fermentation, the lime and alkaline salts, present in milk possessing a faint alkaline reaction, are gradually changed, and the amphoteric reaction of milk disappears, and the acid reaction alone remains, and gradually increases in strength. With the lapse of time this takes place to such an extent that, although the milk remains liquid at ordinary temperatures, a slight increase in temperature, or the introduction of carbonic acid, causes coagulation of the milk. Finally, the casein, even at ordinary temperatures, is decomposed from its combination with chalk, and is precipitated in the form of a white, cohesive gelatinous mass, which encloses all the remaining constituents of the milk.

8. **The Inorganic Constituents of Milk (Mineral, Incombustible, or Ash Constituents).**—The mineral salts of milk, as has already been indicated, form a very important part of the milk, inasmuch as they influence its properties considerably. When one carefully ignites a portion of milk, a mineral residue is obtained possessing a weak alkaline reaction, which, on treatment with strong acids effervesces, and which, therefore, contains carbonic acid, but at the very most not more than 2 per cent. This residue varies in most cases between ·4 and ·86 per cent, and constitutes on an average ·75 per cent of the milk. Closer examination will reveal, in addition to small quantities of carbon, compounds of the metals potassium, sodium, calcium, magnesium, and iron, in combination with chlorine, phosphoric acid, sulphuric acid, and carbonic acid. If it be desired to make a quantitative determination of the ash, and to ascertain in what combinations the above metals are present in the milk, the following considerations must be taken into account:—

(1) The carbonic acid present in the ash of the milk is formed, if not entirely, yet largely, during the incineration of the organic nitrogenous constituents. Carbonic acid is probably not present in chemical combination in fresh milk, or if it be, it is certainly only in such very small quantities that its effect on the solubility of the salts of milk is only of trifling importance. On this account it requires no further consideration.

(2) For the same reasons the sulphuric acid may be excluded, as it occurs, at most, only in traces, and is probably not found in milk at all, and is a product of the combustion of the sulphurous nitrogenous matter. As casein contains ·85 per cent of phosphorus, every 1 per cent of casein will yield, when burned, ·0194 per cent

of phosphoric acid ($P_2 O_5$). Milk containing the average percentage of ash, viz. ·75 per cent, and the average percentage of casein, viz. 3·2 per cent, contains, therefore, in its ash, ·062 per cent of phosphoric acid. Of this ·062 per cent, about 8 per cent is derived from the phosphorus in the casein. In order, therefore, to find the quantity of phosphoric acid which is present as such in milk, 8 per cent has to be deducted from that found in the ash, which is, on an average, 27·5 per cent of the total ash.

If this be done, and carbonic acid be deducted as well as the sulphuric acid, and the small quantity of carbon present, the following results, when the remaining portion is calculated to percentage and the metals reckoned as oxides, are obtained, from which the average percentage of the different mineral constituents of milk may be seen:—

Potassium oxide, ...	25·64
Sodium oxide, ...	12·45
Calcium oxide, ...	24·58
Magnesium oxide, ...	3·09
Ferric oxide, ...	34
Phosphoric acid, ...	21·24
Chlorine, ...	16·34
	103·68
Deduct oxygen for chlorine, ...	3·68
	100·00

If we examine these figures more particularly, it will be found that the chlorine (which without doubt is entirely combined with the alkali metals) and the phosphoric acid, do not suffice to convert the bases present into soluble salts possessing neutral or amphoteric reaction, and that a large quantity of free calcium oxide remains over. Even when we reckon that the casein, which plays the part of an acid, forms a soluble compound with the lime, and that according to Söldner this compound consists of 100 parts of casein and 1·55 parts of calcium oxide, there is yet an excess of the latter. Since the carbonic acid which may be present in fresh milk in a state of chemical combination is far short of being sufficient for effecting neutralization, and since lactic acid is not present in fresh milk, it necessarily follows that other acids—organic acids—are present in the milk and conduce to bring about this amphoteric reaction.

Indeed, Henkel has proved that citric acid is a normal constituent of milk. Whether, in addition to it, other organic acids not yet discovered, may be present in milk, it is impossible to say. If citric acid only is present, milk must contain on an average somewhere about ·25 per cent of it. Till now, perhaps in consequence of the difficulty attending the exact quantitative determination, only ·1 to ·15 per cent has been found. The following, according to Söldner, are the probable combinations in which the mineral constituents of milk are present (neglecting the small traces of iron):—

Sodium chloride, ...	10·62
Potassium chloride, ...	9·16
Monopotassium phosphate, ...	12·77
Dipotassium phosphate, ...	9·22
Potassium citrate, ...	5·47
Dimagnesium phosphate, ...	3·71
Magnesium citrate, ...	4·05
Dicalcium phosphate, ...	7·42
Tricalcium phosphate, ...	8·90
Calcium citrate, ...	23·55
Calcium oxide in combination with casein,	5·13
	100·00

In the above combinations of the mineral salts, if they could be obtained unchanged, they would form ·90 per cent of milk. According to Söldner's experiments, 36 to 56 per cent of the phosphoric acid present in milk, and 53 to 72 per cent of the calcium oxide, are not in solution, but are in a state of suspension in the form of dicalcium and tricalcium phosphates.

To the above-mentioned constituents the following substances must be added, as present in the ash of milk: silica, iodine (in districts near the sea), calcium fluoride, and calcium carbonate. The chemical combinations of the mineral salts of milk are not constant, but vary within certain limits according to the state of health, the feeding, the period of lactation, and perhaps also the age of the animal.

9. The Other Constituents of Milk.—In addition to the chief constituents of milk enumerated and described above, several other substances must be briefly referred to which, although occurring as normal constituents, are always present only in very small quantities, and partly in the gaseous form. These substances, therefore,

as a rule, are not taken into account in the quantitative analysis of milk. Among these are nuclein and lecithin—substances which have been already mentioned as constituents of the caseous matter and of the fat of milk—urea, hypoxanthin, ammonia, citric acid, cholesterin, sulphates, sulphocyanates, carbonic acid, oxygen and nitrogen gas. Small quantities of substances derived from the food of the cow, but which possess no nutritive properties, such as colouring substances and odorous substances, are also found as occasional constituents. Peptone does not belong to the normal constituents of milk, and it is doubtful whether milk, in addition to milk-sugar, contains any other carbohydrate of the dextrine class in small quantity as has been asserted. F. J. Harz has recently found in milk and in milk products such a body, and has named it amyloid.

A peculiar interest attaches to the discovery of citric acid in cows' milk, made by Henkel and confirmed by Anton Scheibe. It is found also in goats' and in human milk. The percentage of citric acid in cows' milk varies considerably. This variation, however, does not depend on the feeding of the cow. On an average, it amounts to ·1 to ·15 per cent of the milk. From the researches of Scheibe it appears that citric acid is a specific constituent of milk, since, like the organic constituents of milk, it is not originally present in the milk-glands in this form.

In condensed milk, viz. that condensed without the addition of sugar, and in sterilized or preserved milk, concretions or bulky precipitates commonly occur, as Henkel has pointed out, which consist almost entirely of pure calcium citrate.

Cows' milk contains only about ·007 per cent of urea. Milk fresh from the udder always contains a certain quantity of gases, oxygen, nitrogen, and carbonic acid—the carbonic acid predominating. They may amount to 6 per cent or more of the volume of the milk. S. M. Babcock claims to have shown that milk contains $\frac{2}{10000}$ of a per cent of fibrin; but this requires further confirmation.

10. The Percentage Composition of Cows' Milk.—Very considerable variations are to be found both in the specific gravity and in the composition of milk drawn even from the same cow at different times (morning, mid-day, and evening). In the whole day's milk, yielded by a single cow on the same day, the variations are within narrow limits. This is still more the case where the samples are representative of a quantity of milk, drawn at the same time; and still more to a quantity of day's-milk from a number of cows (more than five).

The following figures are based on extensive experiments which the author has carried out during a long period of years in different places in Germany, as well as on other available German observations, and represent the average chemical composition of the day's milk of large herds of cows (75 to 150), and the limits within which the percentages of the separate constituents of such milk vary.

	Average.	Limits of Variation.
Water, ...	87·75	87·5 to 89·5
Fat, ...	3·40	2·7 „ 4·3
Nitrogenous matter, ...	3·50	3·0 „ 4·0
Milk-sugar, ...	4·60	3·6 „ 5·5
Mineral matter	·75	·6 „ ·9
	100·00	

The specific gravity of milk of this composition is 1·03165 at 15° C. The ratio of fat to nitrogenous substance is 100 : 103; and the nutritive ratio 1 : 3·74. The composition of the total solids is as follows:—

Fat, ...	27·75
Nitrogenous matter, ...	28 57
Milk-sugar, ...	37·56
Mineral matter, ...	6·12
	100·00

Under ordinary conditions, the milk-sugar is the largest constituent of the milk solids. The nitrogenous matter is slightly in excess of the fat.

The average composition, according to the author's observations, of the whole day's milk of comparatively large herds of cows in North Germany, and of the countries bordering on the German Ocean, which contain large-sized lowland cattle, is as follows:—

Specific gravity, 1·0314—

Water, ...	88·00
Fat, ...	3·25
Nitrogenous matter, ...	3·40
Milk-sugar, ...	4·60
Mineral matter, ...	0·75
	100·00

By the term "total solids" is understood all the constituents of

milk, except water. These amount, on an average, for Germany, in the case of the day's milk of large herds, to 12·25 per cent.[1] The percentage of fat may be stated at 27·75 of the total solids, and 3·4 per cent of the whole milk, and the specific gravity at 15° C., at 1·334. By deducting the percentage of fat from the total solids, the non-fatty solids are obtained. These amount to 8·85 per cent of the whole milk, and have a specific gravity, which remains very constant, of 1·6.

The annual returns show that the specific gravity, for comparatively large herds, if expressed in the form of degrees,[2] rarely rises or falls more than 10 per cent, for milk of the different milking-times, taken for a whole year. Similarly, the rise or fall of the percentage of fat rarely exceeds 30 per cent, of total solids 14 per cent, and of "solids not fat" 10 per cent.

The percentage of the several constituents in milk, obtained at different milking-times, from comparatively large herds, in the course of a year, seldom falls below 2·4 per cent of fat, 10·5 per cent of total solids, 7·8 of "solids not fat", and 1·028 specific gravity. The specific gravity of the total solids rarely exceeds 1·37.

In the case of the milk of single milkings of single cows the limits above stated are, of course, largely exceeded. It is almost unnecessary to cite examples for the purpose of showing to what extent this may take place in certain cases. The milk of single cows, for example, as has been observed by the author, may contain, when the cow is in heat, less than 1 per cent of fat, and shortly before becoming dry as much as 8 per cent. The greatest variation among all the constituents is found in the milk-fat, and the least in the "solids not fat", and the specific gravity. For this reason, in testing milk, for the purpose of forming an opinion of its quality, the determination of the specific gravity and of the "solids not fat" are of especial value.

Few observations have been made with regard to the variation in the percentage of the nitrogenous matter and the milk-sugar.

11. The Relation between the Specific Gravity of Milk and its Percentage of Fat and Total Solids.—That there is a relation between the specific gravity of milk and its percentage of fat and solids is clear; and it is obvious that these three factors are dependent on one another. It is open to question whether the ratio between these

[1] The average percentage of total solids in English milk, according to Vieth, may be taken at 12·90 per cent, and that of the fat at 4·1 per cent; while the total solids in American milk may be taken at 13 per cent, and that of the fat at 4 per cent (Aikman's *Milk: Its Nature and Composition*, Chapter II. A. & C. Black).

[2] The thousandth part of the specific weight is called a degree. The specific weight 1·0332 expressed in degrees would therefore be 33·2.

three factors is the same for all kinds of milk, and whether it holds universally true and is practically useful, and can be stated in a definite form. If these three factors be respectively denoted by the letters s, f, and t, the ascertained specific gravity of the milk-fat by the letter σ, and the unknown specific gravity of the "solids not fat" by the letter n, the value of s will be easily found by the following formula:—

$$(1)\ s = \frac{100 \times n \times \sigma}{n \times \sigma(100 - t) + n \times f + \sigma(t - f)}.$$

If n were like σ a constant quantity, equation (1) would give the desired universally applicable ratio. Whether n is constant or not can be easily discovered. It is only necessary to ascertain the values of s, t, and f accurately, for a large number of different milk samples, in order to calculate the corresponding value of the letters in equation (1).

$$(2)\ n = \frac{s \times \sigma(t - f)}{100 \times \sigma - s \times \sigma(100 - t) - s \times f}.$$

If the above formula be worked out, the surprising result is obtained that n is found, to have always approximately the same value. The author has obtained for a large number of determinations in the North of Germany an average value for n of 1·600734.

From this it may be proved that the specific gravity of the "solids not fat" is approximately a constant number, and that it is possible, therefore, to write down equations for each of the above-mentioned three factors, provided the other two are known.

If in equation (1) we take the value of 1·6 for n, and the known value ·93 for σ, the following formulæ are obtained:—

$$(3)\ t = 1{\cdot}2 \times f + 2{\cdot}665 \frac{100 \times s - 100}{s},$$

$$(4)\ f = {\cdot}833 \times t - 2{\cdot}22 \times \frac{100 \times s - 100}{s},$$

and

$$(5)\ s = \frac{1000}{1000 - 3{\cdot}75(t - 1{\cdot}2 \times f)}.$$

The value of n is not, strictly speaking, constant, but is only approximately so. It varies within very narrow limits. In countries in which the average composition of cows' milk materially differs from that found in Germany, or in parts of Germany where the conditions are exceptional, the average value for n may possibly vary to a small extent, but only so far as to permit of the above equations (3) (4) and (5) always yielding

correct results, provided, of course, that the constant numbers which occur in them are correspondingly changed. The author's practical experience confirms in a very satisfactory manner the accuracy of the results deduced from the formulæ given above, especially (3) and (4), and it has been thus shown that the constants of the formulæ correspond very closely to the conditions prevailing in Germany and England.

Should the numbers obtained in various places, however, despite accurate calculation, not exactly correspond to those directly found, the average value for n must be calculated from equation (2) and used in the following equation:—

$$(6)\ t=\frac{n\times 1\cdot 07527-1}{n-1}\times f+\frac{n}{n-1}\times\frac{100\times s-100}{s}.$$

Taking n as equal to 1·6, and working out the equation, formula (6) is converted into formula (3).

By denoting the percentage of nitrogenous matter, milk-sugar, and mineral matter in milk by x, y, and z respectively, and the respective specific gravities by σ_1, σ_2, and σ_3, we obtain the following formula:—

$$n=\frac{\sigma_1\times\sigma_2\times\sigma_3(x+y+z)}{x\times\sigma_2\times\sigma_3+y\times\sigma_1\times\sigma_3+z\times\sigma_1\times\sigma_2}.$$

As is easily shown, n is constant, either if $\sigma_1=\sigma_2=\sigma_3$, or if the respective ratio of x, y, and z be the same for all kinds of milk. Neither the former nor the latter is exactly the case. Nevertheless the values of σ_1, σ_2, and σ_3 differ very little, as a close examination will show. The respective ratio of x, y, and z is also not unknown. There is always more milk-sugar than nitrogenous matter in ordinary milk; but the value of z in milk of different origin only varies between ·6 and ·8 per cent. That the one condition as well as the other is fulfilled, to a certain extent at any rate, is obvious, since through the combination of both of these favourable circumstances a very approximate constancy of value for n can be obtained.

The specific gravity m, of the total solids, is obtained from the equation—

$$(7)\ m=\frac{s\times t}{s\times t-(100\times s-100)}.$$

For obtaining the value of t (equation 3), and m (equation 7), the author has devised tables, by means of which the value of t can be obtained, by a simple addition, and that of m through subtraction and division.

12. Colostrum (first milking, beastings, *beistyn*).— Colostrum, which is the liquid secreted by the milk-glands both before and immediately after calving, possesses peculiar chemical and physical

properties, and assumes gradually—generally after the lapse of three days from calving—the properties of ordinary milk. During the first hours after calving it is always very rich in solids, and contains large quantities of nitrogenous bodies, of which only about a half are in a state of suspension. It contains only minute traces of milk-sugar, sometimes none at all, but in its place small quantities of other kinds of sugar. It has about the same quantity of, or even less fat, than ordinary milk, and rather more mineral matter. It possesses a yellowish or brownish colour, a peculiar smell, and a slightly salt taste. Its reaction is generally slightly acid, and it possesses a slimy, viscous appearance. It exhibits a variable reaction towards rennet, and on being heated it coagulates. If kept undisturbed, it often separates into two more or less distinct layers. Its specific gravity at 15° C. varies between 1·046 and 1·079. It is the most convenient and only natural kind of nourishment for the young, and newly-born calves should on no account be deprived of it, as it exercises an especial action on the intestinal canals, and possesses also a high nutritive value. It is not suited for use in the dairy. On this account the milk of cows, when they first begin to give milk, is kept separate for four days if the milk be intended for use in churning, or for ten or twelve days if it be intended to use it for cream cheese.

The composition of colostrum changes quickly, hour after hour, from the period of birth, until it assumes the properties and composition of ordinary milk. Of an average composition, therefore, it is not possible to speak. The following figures, however, may serve to give an indication of its nature:—

Water, ...	78·7 per cent.	
Fat, ...	4·0	Total solid matter, 21·3 per cent.
Nitrogenous (caseous) matter, in suspension,...	7·3	
Nitrogenous matter in solution, ...	7·5	
Sugar, ...	1·5	
Mineral matter, ...	1·0	
	100·00	

Especially characteristic of colostrum are certain grape-shaped bodies, the *corps granuleux*, discovered in 1836 by Donné, the diameter of which lies between ·005 and ·025 mm. Henle has named these microscopic bodies, which do not entirely disappear from cows' milk till three weeks after

calving, colostrum corpuscles (fig. 18). They are, despite a widely-spread belief to the contrary, of no importance in the morphology of milk secretion, and it is a mistake to look upon them as the type of the fatty degeneration of the epithelial cells of the milk-gland basket.

According to Eugling, the colostrum of 22 Montavun cows, two to thirteen years old, which had given birth to from 1 to 11 calves, possessed

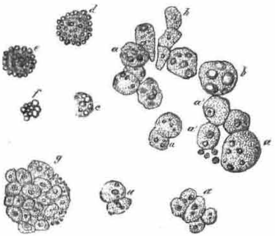


Fig. 18.—Colostrum Corpuscles. (× 300.)
a, Cells showing fatty degeneration; *a'*, cells with nucleus; *b*, cells containing large fatty globules; *c*, cells with partially destroyed membrane; *d*, *e*, cells which have completely lost their membrane; *f*, Donné corpuscles; *g*, *h*, group of cells. (Fürstenberg.)

a specific gravity of from 1·058 to 1·079—an average of 1·068,—and had the following chemical composition:—

	Average Composition.	Limits of Variation.
Water, ...	71·69	76·60 to 67·43
Fat, ...	3·37	1·88 „ 4·68
Casein, ...	4·83	2·64 „ 7·14
Albumin, ...	15·85	11·18 „ 20·21
Sugar, ...	2·48	1·34 „ 3·83
Mineral matter, ...	1·78	1·18 „ 2·31
	100·00	
Total solids, ...	28·31%	23·40% 32·57%.

The ash of the colostrum, inclusive of phosphoric and sulphuric acid formed by the burning of the protein matter, had, on an average, the following composition:—

Potassium oxide, ...	7·23
Sodium oxide, ...	5·72
Calcium oxide, ...	34·85
Magnesium oxide, ...	2·06
Iron sesquioxide, ...	0·52
Phosphoric anhydride, ...	41·43
Chlorine, ...	11·25
Sulphuric acid, ...	0·16
	103·22
Deduct oxygen replaced by chlorine, ...	3·22
	100·00

Nuclein, lecithin, and cholesterin were found to be abundantly present in the colostrum. The sugar found was not milk-sugar, but a sugar capable of direct alcoholic fermentation; and the fat possessed a melting point of between 40° and 44°, which is a very high melting point.

An analysis of ten samples of colostrum, made in the author's laboratory, showed in all cases comparatively large quantities of cholesterin and lecithin. Leucin, tyrosin, urea, animal gum, and in some cases peptones were also found. In the ether extract were found fat and small quantities of free fatty acids and a yellow colouring matter. In addition to milk-sugar, grape-sugar was found, and perhaps also some other kind of sugar. Finally, the ash was found to be richer in the alkaline earths and in phosphoric acid, and poorer in alkalies, than the ash of milk.

13. The Secretion of Milk in the Udder.—The physiological forces at work in the milk-glands, during the period of lactation, are dependent on the special surroundings of the individual animal and on its condition. They give rise not merely to an active up-building of tissue, but they also drive the secreted fluid into the cavities of the glands and udder, and work without any external opposition so long as the udder is not full. As soon as the cavity of the udder is full, however, and when, owing to the continuous accumulation of the quantity of the secretion, it begins to distend, there arises an ever-increasing pressure against the sides of the secreting glands, which most probably does not continue without a weakening reflex action on the physiological forces above referred to. Perhaps this explains the fact, found by experience, that the more frequently an animal is milked in a day, it yields so much the more milk, containing a larger percentage of solids. It has also been found that the quantity of milk obtained is in direct proportion to the percentage of dry matter in the milk, but in inverse proportion to the length of time between the successive milkings. The fact often observed in practice, that milk, when yielded in large quantity, contains less, and in small quantity more, dry substance, may be partly attributed to the action and reaction of pressure. Generally, however, these phenomena are due to other causes. The question as to whether the milk lies in a ready-formed condition in the udder, or whether a part is formed through the excitation of the nerves connected with the milk-secreting organs during milking, in consequence of the withdrawal of pressure in the udder, must be regarded as an open one. The experiments made on this subject have given no decisive results.

The space in the udder, which is occupied by the milk before milking, consists of four milk cisterns, and of a richly-branched network of canals and vessels leading up from them, the finest ends and dilations of which form the gland-basket. When, after milking, the udder begins to fill again, the milk formed must distend the canals and vessels, where it is held by capillary attraction, and where the forward movement of the fatty globules is retarded through congestion and friction, before it reaches the milk receptacle. This explains why it is that, under ordinary circumstances, the percentage composition of fat and of solids in milk steadily increases from the beginning to the end of the process of milking, and its specific gravity decreases; and why the milk which comes last is always richer in fat. The increase of solids is sometimes as great, sometimes less, and sometimes somewhat greater than that of the fat; so that we may well say it is practically influenced by the increase in fat only. This phenomenon becomes more noticeable the longer the time which intervenes between two consecutive milkings is. As a rule, it may be said to take place no longer when the interval between the milkings is less than four hours.

If a similar period intervene between the two milkings in the case of cows milked twice a day, and the conditions influencing the health of the cows are approximately similar, it may be said that between the morning and evening milk, so far as quality and quantity are concerned, there is no difference. If, on the other hand, the intervening periods between the times of milking are unequal, it may be almost always noted that the milk obtained after the longer interval is greater in quantity, but contains less solids; and after the shorter interval is less in amount, but contains a larger amount of solids.

After it had been discovered, as the result of experiments with a few cows, and with shorter intervening periods, that milking three or four times a day gave more milk, and milk richer in fat—occasionally with as much as 20 per cent of an increase in amount, and as much as 25 per cent increase of fat,—than is obtained with two milkings, it was recommended that cows should be milked regularly three times a day. The author will not contend that, as a rule, milking three times a day, under otherwise similar conditions, does not give a larger yield than milking twice a day; but he is convinced, from numerous observations, that the amount of such increase is largely exaggerated. In no case can it be expected in introducing the two-times-a-day milking, instead of the three-times-a-day milking, or *vice versa*, into large herds, that an increase or decrease in yield, similar to

that obtained in experiments carried out on a small scale, will take place. Undoubtedly, in the case of single cows, the expansion of the milk cavity in the udder, and the multitude of gland-baskets and their physiological activity, accommodate themselves to the times of milking. According to the degree in which this takes place, the differences, at first noticeable in the yield, necessarily diminish, and it is highly probable that in most cases, they eventually entirely disappear. In large dairies, in the case of pasturing animals, or where the milk is utilized in large factories, the three-times-a-day milking system is practically inadmissible. If the system of milking three times a day really gives an increase, which has not been definitely proved, its adoption in small dairies may not always be found to pay, when the increased expense, as well as the waste of time and the inconvenience incidental to such a system, are taken into account. Of course, in the case of heavy milking and newly-calved cows, the milking must be done three times a day, or even oftener.

14. Lactation Periods.—The time during which a cow gives a continuous supply of milk, that is, the time intervening between calving and becoming dry, is called the lactation period. This may be taken, on an average, under ordinary circumstances, to be 300 days; and the cows remain dry for the following six or eight weeks. In most cases the milking capacity of the cow reaches its highest point in the course of the first two months after calving, and diminishes from then till the time when it becomes dry. The yield of the cow may become reduced pretty gradually, or perhaps intermittently, and in the latter case frequently occurs in three unequally long intervals, more or less distinctly marked. This natural process is influenced by suitable treatment and management, and especially by an intelligent regulation of the calving-time suitable to the local conditions of feeding.

In the case of richly-fed and well-tended milk cows of average age, the percentage of total solids in the milk almost always increases with the advancement of the period of lactation. At the same time, not only is the percentage of fat in the milk increased, but also the percentage of fat in the dry total solids, so that the milk becomes absolutely, as well as relatively, richer in fat. With regard to the behaviour of the other constituents during lactation, we have up till now few reliable observations. G. Kühn found in the case of cows with which he experimented that generally the percentage of protein, especially the caseous matter, increased with the period of lactation, while the albumin and the milk-sugar showed a decrease.

15. The Age of Cows.—The milk-yielding capacity of good cows increases, year by year, within certain limits, from the first lactation period, and from then decreases with increasing age. It may be assumed that, generally speaking, the milk-yielding capacity of a cow increases up to her eighth year. The age up to which it pays to retain a cow differs in the case of individual animals and different breeds, and depends also on the food and treatment of the animal.

In what way the chemical composition of the milk of single cows varies from year to year with the increase of age has not so far been closely investigated. According to experiments made in Kleinhof-Tapiau, it would appear that in the case of cows which exhibited with increase of age a decrease in their yearly yield of milk, it was found that the percentage of total solids decreased, and to a still greater degree that of the fat. In these experiments the youngest cow yielded a milk containing solids richest in fat.

16. The Effect of Bulling.—The influence which bulling exerts on the secretion of milk, during the period of lactation, varies very much according to the individuality of the cow and her general state. In many cows the bulling passes without a trace of effect, and in others it has been noticed that the quantity of milk decreases considerably, the specific gravity decreases, the percentage of fat is largely reduced, often to 1 per cent, the milk becomes coagulated on heating, and is not acted upon by rennet. These changes, however, even when they have been most marked, always disappear quickly, usually entirely after two days.

It has been noticed that cows, which during bulling yield a milk poor in fat, directly afterwards yield a milk unusually rich in fat, so that, in this way, the early decrease in fat is compensated for by the subsequent increase. The earlier widespread opinion, that the spaying of cows always exercised a favourable influence on the secretion of milk and on the capacity for taking on fat, has proved itself unreliable. Careful investigations carried out on this subject have shown that spaying, even in the case of selected cows, is not to be recommended, if care be taken to render them valuable by good feeding without any operation. Spaying is only to be recommended in the case of cows suffering from nymphemania (constantly in heat).

17. The Working of Milk Cows.—In very many districts in some countries milk cows are used for working purposes, and the result is naturally enough a distinct decrease in their milk yield. The

diminution in milk, however, is generally amply compensated for by the work they effect, and there need be no fear, if working cows are treated with care and intelligence, of their milk losing the ordinary properties of milk. If, however, the cows be subjected to too great a strain, the milk will assume abnormal properties, which will seriously affect its value.

It may be well here to refer to the assertion recently made in America, that the dishorning of cattle has a favourable influence on the yield of milk. As, however, we have enough natural and approved methods of raising the yield of milk in cows, we have no hesitation in condemning this barbarous and unfeeling custom, even supposing it actually does exercise a favourable influence, which is very doubtful.[1]

18. **Feeding.**—It is almost impossible to make any generally applicable remarks on the influence of food on the yield and chemical composition of milk, since this varies, and is dependent on the particular circumstances of the cows. There are cows whose milk-glands possess such great activity that even with scant feeding they give a large yield, which naturally is partly produced at the expense of their tissue. Others, again, yield with rich feeding only small quantities of milk, but become quickly fat; while, lastly, there is another class, and these are the cows which ought to be reared and kept as being best suited for dairying purposes, which yield, with a continuous improvement in food, a steady, unfailing increase in the yield of milk, until they reach, sooner or later, their natural limits, or a limit which is determined by a consideration of the net profits.

The best milk cows are those that are most affected by an increase in the digestible constituents of food, and which respond to that increase, in the most profitable manner, from the dairy point of view. How far the treatment with food, in order to increase the yield and profit, can be developed, has up to the present been but little investigated. Perhaps the limits are less narrow than we are just now inclined to assume, and it might be advisable to prove, by means of experiments, whether it would not pay, in the case of well-

[1] The reason assigned by Professor Fleischmann appears to us inadequate. The extent to which cows of some dairy breeds wound and gore each other with their horns is so great that the practice of dishorning is really humane to the cattle, while it also removes a source of danger to their attendants. The improvement in the milk production asserted to be noticed in America as a result of the practice is no doubt due to the more peaceful life led by the dishorned animals, and to their freedom from the wounds and injuries so frequently inflicted by horns.—*Editors of English Edition.*

tended cows, to introduce feeding rations containing distinctly more digestible nutrients than are at present usually regarded as most favourable. Good milk cows, whose full capacity for giving milk it is desired to develop, require, above all things, food which is not only absolutely but also relatively rich in digestible protein, by means of which the quantity of circulatory protein in the blood may be increased. There can be no doubt that in the case of cows yielding a large amount of milk, the fat derived from the food is utilized for the formation of milk-fat. It seems advisable to the author, therefore, that in the fodder of good milk cows, the percentage of digestible fat might likewise be somewhat increased over what has, so far, been regarded as desirable. The old doctrine that the composition of the solids of milk is little influenced by the nature of the feeding; and that it is impossible to increase the percentage in milk, of any one constituent, by special feeding, has, up to the present time, invariably proved itself correct. It has been asserted, indeed, that an increase in the relative percentage of fat in milk may be obtained by feeding with palm-nut meal and malt combs, but this statement is based on isolated observations, and has not been confirmed in dairy practice.

It cannot be regarded as correct that with increased percentage of the dry-substance of milk all the separate constituents are raised in the same proportion. Nor is it true that the percentage composition of solids for one animal and one lactation period is approximately constant. It is similarly incorrect to suppose that with an improvement in feeding an increase in the yield of milk is obtained, which never affects one or other of the separate constituents. This, at any rate, does not hold good for the fat, since the percentage quantity of fat is subject from day to day, and in the course of a lactation period, to far greater variation than the other less variable milk constituents. The percentage of fat in milk is without doubt most sensitive to all the external influences that affect the yield of milk. Very often it is observed that the cow, when the activity of the milk-glands is temporarily increased in course of lactation, yields not only more milk, but a milk richer in fat, the fat being increased more than the non-fatty solids. For example, this is often seen at the beginning of pasturing in summer. Further, accurate observations on the yield of milk from well-tended and well-fed cows have shown that the average composition of the solids of the milk of single cows is generally proportional to the

average percentage of fat, and that the animals yielding large quantities of milk yield, in the case of liberal feeding, a milk richer in quality. It has also been found that animals whose milk is absolutely richer in fat, at the same time yield milk relatively richer in fat. As proof of this a few figures may be quoted, which the author selects from a number of available data:

	Fat.	Total Solids.	Fat in Total Solids.
(143) Dutch cows (Kleinhof-Tapiau) ...	3·226	11·913	27·08
(100) German cows (Raden)	3·242	11·953	27·13
(24) Short-horn cows (by Dr. Vieth) ...	4·518	13·948	32·39
(24) Jersey cows (by Dr. Vieth) ...	4·908	14·596	33·62

It may be observed, from the above figures, that the milk containing an increased percentage of fat and solids is also always relatively richer in fat.

From all this it would seem that the secretion of milk is to be regarded as an organic process, which is more or less under the influence and control of the formation of milk-fat. This has been clearly demonstrated in the case of the secretion of milk by well-treated and liberally-fed cows.

Hitherto it has been held that cows yielding a large quantity of milk yielded a milk containing a small amount of solids. Assuming that such cows do not receive food sufficient for developing to the fullest extent their milk-forming capacity, this statement may be regarded as generally correct. There are cows, however, which, if richly and liberally fed, not only give a large yield of milk, but also a milk with a high amount of total solids. That this is possible is clear from the predominant action exerted on the percentage of fat by all conditions that influence favourably the yield of milk, and from the observation that the increase in the percentage of fat, if not taking place at a similar ratio, yet increases with the percentage of non-fatty solids.

The most important quality in a milk cow is the capacity of the milk-glands to yield, with certain feeding, the largest possible quantity of milk of the best possible composition. The rearing of breeds of milk cows possessing such properties has so far received little consideration in Germany, yet the prospect of a great advance in dairying is opened up by efforts in this direction, for all the measures taken to increase the supply of milk, such as good feeding, careful breeding, and other treatment, are almost certain to result in

a double reward, due to an increased yield of milk, along with an increased percentage of fat.

The supplying of nourishment of a suitable kind and quality should not be left to the promptings of nature or the caprice of the animal, but should be regulated by regular laws, and varied according to the live weight. For this reason, it has been agreed to regard as the standard of comparison for the measurement of the food requirements of domestic animals the weight of 1000 lbs. (in England and America), or 500 kilos (in Germany).[1] Cows' milk, which is the natural food of young calves, contains, as its nutrient ingredients, water, nitrogenous matter (protein), fat, a carbohydrate, and mineral substances. These nutrients are the same as those on which the cow must be fed throughout her whole life, and which must be daily supplied in digestible forms and in definite quantities. An average cow requires, according to the commonly accepted standards, the following amounts per 1000 lbs. of live weight:—

Dry substance in food, 15 to 35 lbs.; average, 25 lbs.

Containing digestible protein, 2·25 to 2·75; average, 2·50 lbs.

" " fat, ·4 to ·6; average, ·5 lbs.

" " carbohydrates, 10 to 15; average, 12·5 lbs.

" dry substance in the form of coarse fodder 12 to 20; average, 16 lbs.

" salt (in addition), 10 to 70; average, 40 grams.

Cattle require daily, on an average, about three times more water than dry substance. With regard to mineral matters, it may be assumed that these will be found in sufficient quantity in the daily food, if this be supplied in sufficiency and of a suitable character.

The utility of a food depends on the ratio of the amount of nitrogenous nutrients to the amount of fat and the other non-nitrogenous nutrients. None of the different nutrients effects a definite physiological action, but each one has a particular function to perform in the animal system. The nitrogenous matter of food has been named "flesh-forming", since its chief function is to build up and renew the tissue of the animal body; while the non-nitrogenous nutrients have been called "heat-giving", since they chiefly effect the maintenance of heat in the system. As the nitrogenous substance is indispensable for the formation and repair of the animal tissue, and as this can be effected by no other group of nutrients, it follows that the value of a feeding ration is, above all, dependent on its percentage of protein matter. The ratio between the quantity of digestible nitrogenous matter, and the quantity of digestible non-nitrogenous constituents, in a ration, is expressed by a fraction whose numerator is 1. This

[1] 500 kilos = 1100 lbs.

is called the albuminoid ratio. The ratio of 1 : 5, which has been found by experience to be suitable for the feeding of adult cows, may be considered as a standard ratio for purposes of comparison. According as the ratio is less or greater than 5, it is named a narrow or wide ratio. If the ratio of nutrients is to be calculated, it is necessary, in the first place, to reduce both the groups of non-nitrogenous nutrients, *i.e.* the fat and the carbohydrates (digestible non-nitrogenous extract and digestible fibre), to a common value. This is necessary in order that the quantity of fat may be stated in its equivalent amount of carbohydrates. For this purpose, the quantity of fat is multiplied by 2·5, which is called the starch equivalent of fat, since it has been ascertained by experiments that by the *digestion of one part of fat (by weight) as much heat is produced approximately* as from the digestion of 2·5 parts of carbohydrates. In order, therefore, to find the nutritive ratio of a ration, it is necessary to multiply the amount of digestible fat by its starch equivalent. This is added to the amount of digestible carbohydrates, and the total divided by the amount of digestible nitrogenous substance. An example may serve to make this clear.

A ration consisting of 8 lbs. of average clover, 10 lbs. of oat straw, 20 lbs. of roots, 6 lbs. of oats, 1 lb. of rape-cake, and 2 lbs. of earth-nut cake from shelled nuts, has to be examined. From tables which will be found in any text-book of agricultural chemistry,[1] the following figures may be found, which represent the average composition of the dry substance of the individual foods and their digestible nutrients.

	Dry substance. lbs.	Protein. lbs.	Non-nitrogenous extract. lbs.	Fibre. lbs.	Fat. lbs.
8 lbs. clover hay, ...	6·72	·56	2·02	·94	·10
10 lbs. oat straw, ...	8·57	·14	1·67	2·34	·07
20 lbs. roots, ...	2·40	·22	1·82	·18	·02
6 lbs. oats, ...	5·26	·48	2·55	·13	·26
1 lb. rape cake, ...	·90	·25	·23	·01	·08
2 lbs. earth-nut cake, ...	1·80	·86	·48	·02	·14
Totals, ...	25·65	2·51	8·77	3·62	·67

From the above we find that the ration contains 25·65 lbs. of dry matter, of which 15·29 lbs. are in the form of coarse fodder. The following quantities are the amounts of digestible constituents:—2·51 lbs. of nitrogenous matter, $8·77 + 3·62 = 12·39$ lbs. carbohydrates, and ·67 lb. of fat. The nutritive ratio is 1 : 5·6 for

$$\frac{·67 \times 2·5 + 12·39}{2·51} = 5·6$$

[1] See Johnston's *Elements of Agricultural Chemistry*, 17th edition, revised by Dr. Aikman, pp. 382–85 and p. 465 (Blackwood & Sons).

It should be noticed, however, that the digestibility of the nutrients is by no means inconsiderably lessened by the addition of bulky fodder, containing much non-nitrogenous substance, to a ration. It must not be forgotten that such a lowering of digestibility would be exercised in the case of the above ration by the 20 lbs. of turnips which it contains.

It is hardly necessary to say that putrefying food of any kind should on no account be given to milk cows. Milk cows must also not be fed with beans, peas, lupines, pea-straw, or with large quantities of barley-straw.[1] The most suitable foods, and those which have the most favourable action, besides good grass and hay, are the grain of cereals, especially oats, and the different kinds of bran, especially coarse wheat bran. All kinds of roots, including mangel and chopped turnips, may be mixed with the eighth part of their weight of good cut straw, and potatoes with about half their weight of straw. Approximately about eight kilograms potatoes per day per 500 kilograms of live weight (17½ lbs. to 1100 lbs.) may be recommended. If large quantities of potatoes are used in feeding it is best to steam them. Where the conditions of the farming are such that very watery foods, such as distillery refuse and sliced roots, have to be given, which are better adapted for fattening cattle than for milk cows, care should be taken that the cows receive, if possible, at least 5 kilos. of coarse fodder daily per 500 kilos. of live weight (11 lbs. per 1100 lbs.), and also ample quantities of digestible protein in their total ration. Where roots are used, care should be taken to measure exactly the quantities which are daily given. It is impossible, however, to fix a precise limit to the quantity which it is advisable under all circumstances to allow. As soon as the rations are no longer eaten by the cows with appetite, and the roots are no longer perfectly digested, both the flavour of the milk and the milk-fat are in danger of being affected by the root feeding. In the case of feeding with distillery refuse, the mangers, which are apt to become contaminated with acid and fungoid ferments, should be carefully kept clean, and, along with all places which come in contact with the food, should be washed with freshly-prepared milk of lime at least once a week.

The following conclusions drawn from practice are well worthy of attention, even if they are not to be invariably relied on:—

Milk-fat becomes hard in its texture, in the case of feeding with peas,

[1] In reply to an inquiry by the translators, Prof. Fleischmann writes that all the foods mentioned can be successfully and properly used in feeding milk cows, provided they form a moderate proportion only of a ration, otherwise suitable; but that if used in excess they produce an unfavourable influence on the milk products. Thus barley-straw has been found to influence quite perceptibly and unfavourably the flavour of butter, and linseed-cake tends to produce a hard butter that has not the desired texture. Experience in Germany has also gone to show that such foods as beans, peas, and lupines can be more freely and advantageously given to feeding cattle than to milk cows; and that when given to the latter, it should only be in moderate and suitable quantity.—*Editors of English Edition.*

vetches, rye, linseed-cake, cotton-seed cake, palm-cake, and palm-nut meal.

The milk-fat becomes soft when rape-cake, oats, and wheat bran are used. Wheat, barley, and rye, earth-nut and cocoa cake, and malt combs have no distinct influence on the texture of milk-fat.

When oil-cakes are used, it should be a rule that not more than 2¼ lbs. at the very most of each kind of cake should be given per head of cattle. The value of oil-cakes for milk-production may be placed in the following decreasing order. The most useful is undoubtedly rape-cake, then follow in the second place palm-cake and palm-nut cake, while cocoa, earth-nut, and cotton-seed cakes, sunflower and hemp cakes, follow in the third place. It is quite an erroneous belief to suppose that the cakes mentioned in the third division exercise a generally detrimental effect on the production of milk. This is by no means the case. These cakes have a distinctly marked efficacy, as is also more especially the case with rape-cake and palm-cake. If the milk-fat be hard and brittle, it can with certainty be made soft and oily by using rape-cake, and by using palm-cake, milk-fat which is soft and oily can be made to assume a firm consistency. In winter rations, which consist largely of straw and potatoes, a pound of rape-cake should never be omitted. According to the experiments of Adolf Mayer, the melting point and also the firmness of butter are dependent on the food, in so far that easily digestible carbohydrates lower the melting point, while feeding with fodders poor in sugar raises it.

It is not advisable to feed milk cows with linseed-cake. Malt combs must also be used with great caution, as under certain circumstances they exercise a peculiar irritating effect on the sexual organs.

In the production of excellent and good keeping butter, the best results may be most certainly obtained by using, for the winter feeding of cows, good hay and oat straw, with moderate quantities of beets or carrots, and with oats, wheat bran, and rape-cake.

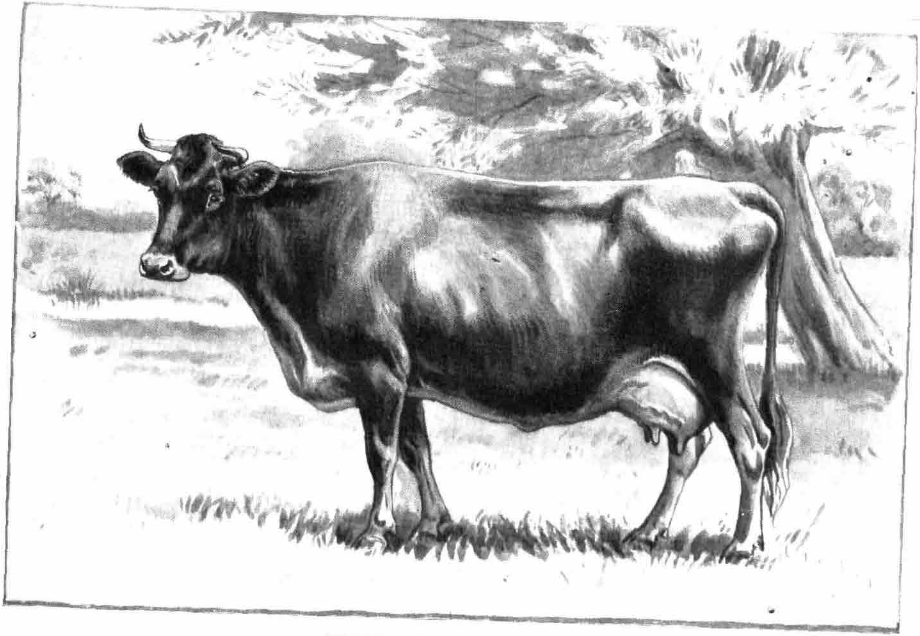
Care should always be taken that the food supplied to cows is not only nutritious and concentrated, but also palatable. In the rations provided, suitable quantities of salt should not be omitted, as well as pure water of a proper temperature. The addition to the food of small quantities of aromatic herbs may sometimes prove very useful. Alterations in the mixture of the food rations are scarcely felt, if the composition of the food, in digestible nutrients, is maintained at the same point, and if the alterations be slowly and carefully effected. On the other hand, sudden changes always produce distinct disturbances on the yield of milk, a point which may be specially shown by analysis of the milk. Changes in food do not, however, produce a distinct effect in changing the milk from day to day. The effects are only clearly shown after the lapse of several days.

It is well known that milk may be watered through the animal body, either intentionally or unintentionally. The more the custom of buying milk according to composition prevails, the more rarely will this kind of adulteration take place.

19. Milk Yields.—The amount of the average yield which the different breeds of cows give in their own districts is of minor interest. It is more instructive to inquire what is the average yearly yield of a cow at present for the whole of Germany; and whether this may be regarded as satisfactory. There are in Germany (and in this matter we need not deceive ourselves) still large districts, in which herds of cows, 20 and 30 in number, do not yield on an average more than 2000 kilos. (4400 lbs.) of milk per annum. On the other hand, there are isolated agricultural districts, in which herds of 80 and 100 yield, on an average, 4000 kilos. (8800 lbs.) of milk per annum. There is no doubt that in Germany, on the whole, excepting in narrowly limited and advantageously situated districts, the feeding of milk cows, both in quantity and composition of the food, is not yet in proportion to their natural milk-yielding capacity. We are yet far from having reached the limit of the possible economic development of the milk-yielding capacity of the cow. Whether, under the present conditions of German dairying, we have reached a yearly milk yield of 2500 kilos. per 500 kilos. (5500 lbs. per 1100 lbs.) of live weight, that is, five times the amount of live weight, the author does not venture to decide; it is certain, so far as his experience goes, that this yield has not been exceeded. With regard to the endeavours which have been made to increase the milk yield of our cows by intelligent breeding, much success, on the whole, has not been attained. The solution of the much-discussed question as to how to improve the quality of the milk, up to the present time has hardly even been considered.

In the case of single cows, unusually large yields of milk have been observed, amounting to 8000 kilos. (17,600 lbs.) per annum, or 36 kilos. (79 lbs.), and even more, per day. Cows giving the largest quantity of milk, however, do not always give the most profitable yield.

The relative moistness of the air, and the percentage of water in the food, especially in the case of grass and the ordinary roots, which vary in the different districts according to their geographical position, appear to exercise, through their continued operation, a powerful influence on the



JERSEY COW—"CHESTNUT II."

Bred by Mr. Baxendale, Bonnington, Ware. Winner of 1st Prizes in Butter Competition, 1892–93.

development of the milking capacity of cows, and mainly to fix the average yearly yield of milk of the different groups of cattle in their native districts. Those kinds of cattle which are recognized as the richest milkers, the black and the gray coloured Dutch breeds of the North German lowland cattle, as well as those breeds, the milk of which is characterized by its extraordinary richness in fat, such as the Channel Islands breeds, the Jersey, the Guernsey, and Alderney, have their homes in districts with a maritime climate of the above-described nature.

Despite the commonly and emphatically expressed statement that animals yielding a large supply of milk, always yield a milk with little fat and solids, the question may be asked whether the animals and herds in which this fact has been noticed are always fed with a sufficiently rich and nourishing diet—sufficient to enable them to attain to the limit of their milking capacity. If this—and the author believes that those who have large experience of practical dairying have not a doubt on the subject—is not generally the case, we must freely admit that we know very little with regard to the capacity of cows, yielding large quantities of milk, when they are fed in such a way as to enable them to yield up to their full capacity. There is no necessity, from a physiological point of view, for inferring that a large milk capacity is necessarily always united with a low percentage of fat and solids.

20. **Milk-yielding Capacity of Cows.**—A high milk-yielding capacity, *i.e.* the capacity to yield, within a certain time, a large quantity of milk in proportion to live weight, and the secretion of a quantity of milk greatly in excess of what is required for the sustenance of the young, are independent of the form of the skeleton and the form of the body of the mammal. Among the different kinds of ruminant domestic animals, this capacity is most strongly developed in the case of the goat, and least so in the case of the sheep. The power of yielding large quantities of milk is not a natural characteristic of the animals, but has been gradually developed in them, in the course of time, through the influence of treatment by man. This property is connected with hereditary qualities, but it is also, in a very variable degree, an individual quality. Therefore, when special groups or breeds of cattle are spoken of as being rich milkers, this denotes nothing more than that it has been found by experience that rich milking cows are more common in these breeds than in others. The capacity, which has been artificially developed in a herd or breed, for yielding a large quantity of milk, may be very quickly and very largely lost again, if care be not continually taken to maintain the

inherited property to its full extent. For this purpose a proper selection of breeding animals must first be intelligently made, and a careful superintendence of subsequent breeding, rearing, and suitable feeding must be exercised, while attention, careful treatment, and every other precaution must be exercised in regard to such circumstances as may exercise an influence on the milk yield.

A thoroughly reliable judgment on the value of a cow can only be obtained from an exact record of her actual performances. Since, in the case of calves and stirks, there can be no such record, and in the case of cows which are for sale, till now, unfortunately, such records have only been available in very few cases, in order to obtain a standard for judging this question, it is very common to have recourse to certain external properties, such as the shape of body, &c., which stand in direct relation to the usefulness of the cow, and give very probable indications with regard to her value. Among external appearances which testify to high milk-yielding capacity the following should be noted:—

(1) A very powerfully developed udder, which ought in no case to be fleshy. A good milk udder is broad, and stretches back to the neighbourhood of the sexual organs, and in front to the neighbourhood of the navel; while on its lower surface it is well rounded and not pointed. The teats should be set wide apart, and in the full udder should point outwards. The so-called secondary teats should not be wanting.

(2) A rich net-work of fine knotty veins, strongly developed milk veins, and broad milk cavities, covering the entire udder, and showing distinctly through its soft skin. The development of the whole system of milk *veins gives no reliable information as to the amount of blood circulating* in the udder, since a portion of the blood flows through the pubic vein of the sexual organ, and there may also be found in fleshy udders highly developed veins.

(3) In the perineum the occurrence of numerous narrow folds lying in regular order beside each other, which are especially well seen in an empty udder, are soft to the touch, and are very loosely connected with what lies under them.

(4) A dusty secretion of fine, hairy scales, on rubbing the greasy skin of the udder and of the perineum.

(5) Fine glossy hairs, fine thin horns, fine hoofs, a widely-spread escutcheon, and a fine elastic skin. As these properties are dependent on a strongly developed cutaneous gland system, one has a certain right to infer from their presence a large development of the milk-glands, which are likewise included among the cutaneous glands. The milk-yielding capacity of an animal is widely believed to be indicated by the condition

of the hairs around the nose, the eyes, the ears, and the stomach, the inside soft portions of the bone, the anus, the tail, and the hoofs.

(6) A general feminine appearance of the whole body. This is important, inasmuch as the activity of the milk-glands is intimately connected with the discharge of the functions of the sexual organs of the female animal.

(7) *A fine head and tail, and fine limbs; in short, a fine bone system,* carrying a weighty body which has been built up by previous rich feeding.

(8) A barrel-shaped belly, deep, and the hind part of which should not be tucked up, indicates the existence of good organs of digestion and the capacity of making good use of food.

(9) A wide distance between the tuft of hair on the line of the back and the edge of the frontal bone, wide interspaces between the spinous process of the chest and the lumbar vertebræ, and a large space between the ribs, as indications of a long chest and a lengthy body.

(10) A deep breast, as wide as possible, and a deep, broad pelvis.

The presence of the above characteristics may be taken as an indication that the animal belongs to a carefully developed, good breed.

Although none of the above indications can be regarded as infallible, all are worthy of careful attention. Bulls for breeding should be regarded as specially valuable when they have had for their ancestors cows with feminine qualities and good milk yields. Special care should be taken, in the case of a bull, to have an animal with an equable temper and a body free from defects. External signs of the latter are fine skin, glossy hair, fine horns, widely-placed ribs, a broad posterior, and a well-formed escutcheon. Great stress is also laid on having the four rudimentary teats of the scrotum well formed, and placed relatively in proper position.

21. **Milk-faults.**—Under the designation of milk-faults were formerly described the extraordinary behaviour shown by milk, which sometimes suddenly occurred from causes quite unknown, and which seriously interfered with the dairy industry. When we read that, in the period between 1815 and 1830, in an agricultural district of Mecklenburg, the disease of blueness in milk lasted for eight years, and that in earlier times, in the best agricultural districts of Schleswig-Holstein, butter was unsaleable owing to the fact that the cream became cheesy in summer for months at a time, we realize that the subject of milk-faults possesses the greatest practical interest. It is of less practical importance at the present time, as such defects seldom now occur. As the practice has extended of creaming milk by centrifugal force, a practice which permits any quantity of milk to be dealt with in a few hours, and as the use of ice in the treatment

of milk has become common, and the necessity of taking suitable precautions has become recognized, the more rarely have such milk defects shown themselves. They still exist in various places in small dairies, but in large dairies in which intelligent and clean methods of working are followed, they no longer, and, indeed, should no longer exist.

Although the changes which milk in certain cases undergoes have not been fully elucidated, we know, nevertheless, that the causes are for the most part not to be found, as was formerly surmised, in the chemical condition of the food, the condition of the soil or pasture-land, the illness of animals, &c., but are to be sought for in the activity of lowly organized forms of life. Only a few diseases are traceable to other sources.

It was not uncommon in the past, for milk which had been standing for about two days for the purpose of creaming, to become subject to putrid fermentation, to curdle prematurely, to assume a bitter taste, to become red or yellow in colour, stringy, slimy, or soapy in texture; or for the cream, after 24 hours' standing in the cream-vat, to become curdy, stringy, and bitter in taste; or such difficulties might only show themselves in the butter. Such undesirable phenomena rarely occur now in the larger dairies, and if so, only in the case of the cream. Should they threaten to manifest themselves, it is now easy to combat them if the desire and requisite knowledge are possessed by the dairyman.

With regard to changes commonly occurring in milk or cream, which are not caused by ferments, the following may be mentioned:—

Milk in which Cream Rises Slowly (Lazy or Dead Milk).—This fault is only found to any extent when milk is treated with ice. It manifests itself in a striking diminution of the yield of butter under ordinary treatment, even when there is an equal, perhaps even an increased, percentage of fat in the milk. In order to prevent its development the milk should be creamed by centrifugal force, or by the Holstein process, or should be churned as whole milk. The milk of cows which have been long milked is often subject to this unwelcome fault. It not merely occurs in autumn, as has been asserted, when the cows are for the most part becoming dry, but also in the spring, shortly before they receive green food, or are turned out to pasture. Undoubtedly it arises from the fact that the original condition of the nitrogenous matter of the milk becomes changed in an abnormal manner, so that a large portion of the fatty globules experiences an opposition which prevents them from rising freely. It has been noticed that milk which exhibits a difficulty in creaming contains less calcium phosphate than ordinary milk.

Milk Difficult to Churn. — The cause of this fault, which greatly impedes the churning of milk or cream, and which, indeed, can even make it impossible, may be traced for the most part to gross violation of the rules of dairy management. Occasionally, perhaps, bacteria may also be implicated. When it shows itself in milk from old milking cows, churning is often rendered possible by raising the temperature, under certain circumstances, up to 25° C. Again, cream sometimes becomes excessively soured, and hence is difficult to work. It may be made suitable for butter-making by treating it with a soda solution (200 grams to 1 litre of water), so as to make it very slightly alkaline, and then again very cautiously making it slightly acid with hydrochloric acid (12 c.c. of the commercial acid to 1 litre of water).

Sandy Milk.—This fault, it would seem, is essentially caused by the peculiar condition of the food, or by disease of the cow. It arises from the fact that, inside the vessels and canals and milk-cisterns of the udder, phosphate of lime is separated out in fine crystals, and causes the stoppage of the milk-tracts of the teats. Inflammation of the udder arises, accompanied by the formation of milk stones and concretionary nodules in the udder.

Further remarks on the subject of milk-faults will be found in Chapter III., where the micro-organisms and their influence on dairying and dairy products are treated.

As an appendix to Chapter I., some remarks on the properties of goats', sheep's, and mares' milk may properly find space here.

22. **Goats' Milk.** — In Germany, the milk of goats, with the exception of a very small proportion, which is used in the manufacture of cheese, is directly consumed, and is used in the small dairying districts as a substitute for cows' milk. As it is admirably suited for this purpose, it appears desirable that as large an increase as possible in the use of goats' milk should take place, and this all the more because tuberculosis, a disease which is very widely spread among so many breeds of cows, and which is communicable to mankind, is unknown in goats. Goats' milk has a white colour, very often a slight yellowish tinge, a weak characteristic smell and flavour, and a slightly slimy consistency. On an average, it is richer in solids, especially in soluble nitrogenous substance (albumin), than cows' milk, and is less easily creamed. It would appear that the fatty globules are, on an average, somewhat smaller than those in cows' milk. The smell of the he-goat, which is common in goats' milk, is not a characteristic of the milk itself, but is

peculiar to the skin of the goat (fig. 19), and is imparted to the milk externally.

In the year 1883, 2,600,000 goats were kept in Germany, that is to say, they numbered 5·8 for every 100 inhabitants. Between the years 1873 and 1883 the number of goats kept increased by 13·8 per cent. It is a well-known fact that goats are characterized by a high milk yield. If we take the live weight of a goat at 30 kilos. (66 lbs.), and the annual yield of milk at only 300 kilos. (660 lbs.), it will appear that goats yield in

Fig. 19.—Pyrenean Milking Goat.

milk ten times their live weight. Animals with large milk-yielding capacities can, if well fed, yield annually 800 kilos. (1760 lbs.), or even more. Goats carry their young, on an average, about 154 days, and the lactation period is four to five months. The time of their milk-yielding period in the year is generally about six months, less frequently four months, and on occasion it may extend to ten months. So far as investigations have shown, goats' milk on an average has the following composition:—

Water, ...	85·5
Fat, ...	4·8
Caseous matter, ...	3·8
Albumin, ...	1·2
Milk-sugar, ...	4·0
Mineral matter, ...	·7
	100·00
Total solids, ...	14·5%

The specific gravity varies between 1·0267 and 1·0380, and may be taken on an average as 1·033, at 15° C. In § 9 it has already been noted that goats' milk, like cows' milk, always contains citric acid.

23. Sheep's Milk.—On many of the larger estates of North Germany, every year in July, after the lambs have been weaned, the ewes (fig. 20) are milked for a short time, but, as a rule, for not more than fourteen days. The milk obtained is made into cream. It

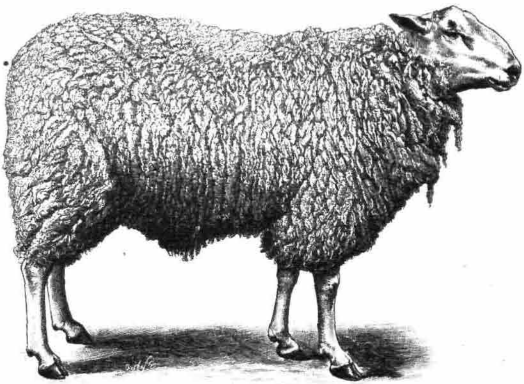


Fig. 20.—Friesian Milking Sheep.

possesses a white yellowish colour, and a characteristic weak, and not very pleasant, smell and taste. It is richer in solids than cows' milk, sours more slowly, and requires for coagulation more rennet than either cows' or goats' milk. It creams with difficulty, and yields a soft oily butter, not suitable for keeping, and possessing an unpleasant flavour. The fatty globules are, as a rule, larger than those either of cows' or goats' milk.

In the year 1883 there were over 19,000,000 sheep in Germany, which gave, on an average, 42 to every 100 inhabitants. From 1873 to 1883 the number decreased, owing to causes which are well known, and need not be referred to here, by 23·3 per cent. Although it has been affirmed that milk sheep can give a large supply of milk, up to 700 kilos. (1540 lbs.)

yearly, the amount that is obtained, on an average, is only about 50 to 70 kilos. (110 to 154 lbs.). If the average weight of a sheep be taken at 40 kilos. (88 lbs.), and the yield of milk annually at 60 kilos. (132 lbs.), the sheep may be said to give a half more milk than its live weight. Sheep carry their young, on an average, 154 days. The lactation period may last about four months, and the time during which the sheep yields milk from four to six months in the year. Examination has shown that sheep's milk is, on an average, of the following composition:—

Water, ...	83·0
Fat, ...	5·3
Caseous matter, ...	4·6
Albumin, ...	1·7
Milk-sugar, ...	4·6
Mineral matter, ...	·8
	100·00
Total solids, ...	17·00%

The specific gravity of sheep's milk probably lies between 1·035 and 1·041 at 15° C. The tables, which are suitable for reducing the specific gravity of cows' milk at any temperature to 15° C., are not available in the case of sheep's milk. The results of seven years' consecutive examination of sheep's milk of old milking (of the Boldebucker) breed, at Raden, by the author, gave an average specific gravity of 1·0369 at a temperature between 12° and 18° C. The average composition was as follows:—

Water, ...	75·400
Fat, ...	11·773
Caseous matter, ...	6·475
Albumin, ...	1·639
Milk-sugar, ...	3·651
Mineral matter, ...	1·062
	100·000
Total solids, ...	24·600%

It is well known that the most celebrated of French cheeses—the Roquefort—is made from sheep's milk.

24. Mares' Milk and Buffalo Milk.—Mares' milk has been made the subject of searching investigations, because some nomadic horse-rearing tribes inhabiting the steppes of the south of Russia and the interior of Asia prepare Koumiss from it—a beverage which has been thought to have a good effect in certain diseases. In Germany, mares' milk is never obtained or used, because Koumiss,

whenever wanted, can be made out of the skimmed milk of cows. Mares' milk is characterized by a comparatively small percentage of total solids, and an exceptional richness in milk-sugar. It possesses a watery appearance, a white or bluish colour, and a sweet taste.

Mares yield milk, on an average, for 340 days. The mares of Tartary are said to remain occasionally in milk for two years, and to yield 200 to 225 kilos. (440 to 495 lbs.) of milk annually, exclusive of the milk consumed by the foal. According to researches, the composition of mares' milk is as follows:—

	Average.	Variations.
Water, ...	90·7	92·53 to 89·05
Fat, ...	1·2	·12 „ 2·45
Nitrogenous matter, ...	2·0	1·33 „ 3·00
Milk-sugar, ...	5·7	4·20 „ 7·26
Mineral matter, ...	·4	·28 „ 1·20
	100·00	
Total solids,... ...	9·3%	

The specific gravity is practically the same as cows' milk.

Buffalo milk is not known in German dairying. In the districts in which tame buffaloes are kept, their milk is highly prized, on account of its richness in fat and its pleasant flavour. It has, however, been very slightly investigated. In colour it is slightly yellowish.

The milk-yielding period of the buffalo lasts probably for ten months, in some cases even to eleven or twelve. During a year, buffalo cows may yield, on an average, somewhere about 800 kilos.—indeed, if carefully treated and well fed, the yield of milk may amount to 1500 kilos. (1760 to 3300 lbs.) and even more.

Two samples of buffalo milk investigated by the author, one of which came from Transylvania and another from Roumania, had, on an average, the following composition:—

Water, ...	82·93
Fat,...	7·46
Nitrogenous matter, ...	4·59
Milk-sugar, ...	4·21
Mineral matter, ...	·81
	100·00
Total solids, ...	17·07%

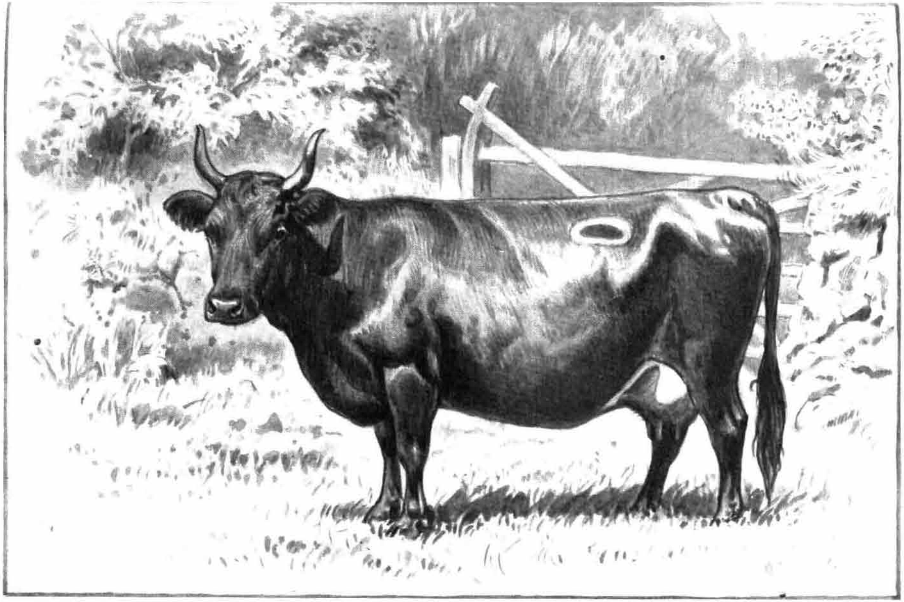
The Roumanian sample had a specific gravity of 1·0339 at 15° C.

CHAPTER II.

THE EXTRACTION, IMMEDIATE SALE, AND THE TESTING OF MILK.

25. **Milking.**—It is of the greatest importance, for the purposes of improving the milking capacity of a cow, and obtaining the largest possible quantity of fat, that the operation of milking should always be carried out in a proper manner. The milk last yielded, as has already been mentioned in § 13, is always the richest in fat. In milking, the udder should be perfectly emptied at each milking; and the cows should, above all things, be treated with the indulgence, quietness, and gentle handling required by their nature. Furthermore, the same person should not attempt to milk more cows than he is able to accomplish properly; and the individual cow, during the period of lactation, should, if possible, be milked always by the same person. It is only when milking is carried out by intelligent, careful people, and the cow is hand-milked, that the usefulness of milk cows can with certainty be developed and maintained, and it is only those who are entirely ignorant of the nature of the milking operation who can abandon themselves to the idea of using milking machines of any description—for example, milk tubes.[1] The use of milk tubes is only permissible in the case of disease of the udder of the cow. Milking should be done either with the whole hand, or, as is customary in the hilly districts of South Germany, only with the first and middle finger, with the assistance of the bent thumb. On no account must it be omitted to press the udder gently and repeatedly between the hands, not merely at the beginning of milking, but also during the process of milking. The custom prevalent in these hilly districts exercises a greater strain, but is far cleaner than milking with the whole hand, since by the latter method it is almost impossible to avoid bringing the milk into contact with the palm of the hand, which is often very dirty. It is hardly necessary to say that the hands of a milker should be washed before milking, and whenever necessary, the udder and the teats should be carefully cleansed.

[1] When this sentence was written by Prof. Fleischmann, the Thistle Milking Machine had not been invented.—*Editors of English Edition.*



DEXTER COW—"ROSEMARY".

Property of Martin J. Sutton, Esq., Reading. Winner of 1st Prizes in Dublin in 1884 and 1885, and at the Royal Agricultural Society's Show, Windsor, 1889.

Nevertheless, cleanliness in the byre is still believed to be neglected in most of the larger agricultural districts of Germany, more especially in North Germany. Very much can be done, by means of the greatest possible cleanliness in milking, to improve the keeping quality of milk, and to give uniformity to the manufacture of the dairy products. Milk which has been handled without the due observance of cleanliness, especially milk which has been contaminated with cow-dung, or with the dusty particles of hay, is very difficult to sterilize. On the other hand, the sterilization of milk which has been handled in a cleanly manner is comparatively easy to effect. The milk which first comes from the teats should be put aside, and not mixed in the milk-pails with the rest of the milk; and in milking (fig. 21) old cows which have been giving milk for some time, a sample of the milk from each teat should be tasted, in order if necessary to put aside the whole milk of the cow.

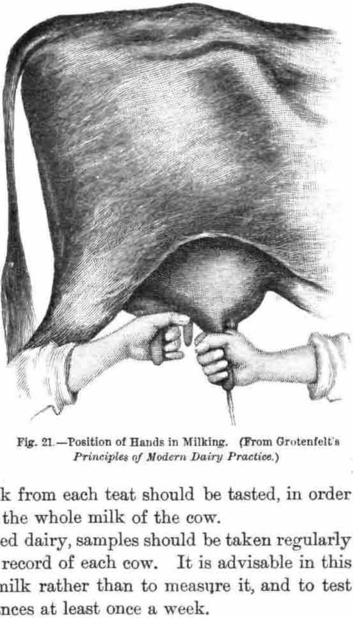


Fig. 21.—Position of Hands in Milking. (From Grotenfelt's *Principles of Modern Dairy Practice.*)

In every well-regulated dairy, samples should be taken regularly in order to ascertain the record of each cow. It is advisable in this operation to weigh the milk rather than to measure it, and to test the milk in all circumstances at least once a week.

In the hilly districts of South Germany milking is done by men, but in North Germany it is generally done by women. When the cows are restless or hold back their milk, the cause always lies in a disordered condition of the udder, whether due to accumulation of blood in the veins, as is believed by Fürstenberg, or to its accumulation in the arteries of the

udder, as is believed by Von Rueff. Force in such a case will never help matters. Many cows have warts on the teats, which increase the difficulty of milking. *It is asserted that when the warts are injured, the blood* flowing from them may cause formation of new warts where the blood falls and dries.

26. **Treatment of Milk after Milking.**—After milking, everything depends on treating the fresh milk in such a way that it may undergo the least possible change before it is used or manufactured. For this purpose care ought to be taken to provide the conditions most favourable for its keeping. The milk should be removed as quickly as possible from the byre, and from any buildings in immediate communication with it, and should be placed in a room with pure fresh air. If it is not to be immediately used, it should be at once strained and cooled quickly to at least 12° C. The lower the temperature to which it is cooled and kept at, the better will it keep. If there be no ice to effect this, the keeping power of the milk may be improved by Pasteurizing, a process well suited for milk *designed for consumption*, which has to be kept for some time before it is used. It cannot be doubted, however, that the spontaneous coagulation of milk is delayed by Pasteurizing, and at ordinary *temperatures*, only takes place, on an average, twenty-four hours later than in the same milk which has not been Pasteurized, but which has been otherwise subjected to the same treatment. Moreover, the practical carrying out of this process may be regarded as very unreliable. Especially is this the case if the hot milk, when removed from the Pasteurizing apparatus, to be cooled down to the necessary temperature of at least 12° C., comes into contact with air heavily laden with spores of ferments.

The addition of chemicals, so-called "preservatives" to milk, such as bi-carbonate of soda, boracic acid, salicylic acid, peroxide of hydrogen, &c., is, under all circumstances, to be emphatically condemned on principle. The two first-named preservatives act only temporarily, by neutralizing the free acid present in the milk, and by dissolving some of the coagulated caseous matter, but instead of arresting the lactic fermentation, they actually help it. The other preservatives exert an antiseptic property.

In various places the creaming of milk by means of the centrifugal separator, and also the cooling of warm milk fresh from the cow, is allowed to take place in the byre itself, or in some room in immediate connection

with the byre. It is unnecessary to say that such a practice is totally against all rules of proper dairying.

By the Pasteurizing of milk is understood a process of heating the milk, for a short time, under the boiling point of water (between 56° and 80° C.). Milk is usually Pasteurized by placing it in the inside of a Pasteurizing apparatus, and then heating up to 70° or 80° C., and subsequently cooling to 12° C. It has been proved by experiment that the bacilli effecting lactic *fermentation are, for the most part, destroyed by a momentary exposure* of the milk to a temperature of about 80° C., and the vitality of the remaining bacilli, along with the rest of the lower micro-organisms present in the milk, is so impaired that their action is temporarily stopped, and their development checked for a time. If this process be carefully carried out, *Pasteurized milk* does not exhibit, or exhibits only to a very slight extent, that peculiar unpleasant taste possessed by boiled milk, which is so disagreeable to many people. We shall have something to say in a subsequent chapter on the *Pasteurizing of milk*.

Fig 22.—Lawrence Refrigerator.

For the purpose of effecting the rapid cooling of milk for general use, the *milk-cooler or refrigerator* (fig. 22) constructed on the plan designed by Lawrence is thoroughly to be recommended. It is able to treat perfectly from 200 to 1200 litres (44 to 263 gallons), of milk in an hour.

It is believed in America that milk should be aired by means of special apparatus, in order to free it from the so-called animal smell. In Europe this custom is not general, and in Germany it is regarded as useless and unnecessary.[1]

27. The Distribution of Milk.—In the moving about of milk, it is necessary to protect it from rapid fermentation, violent shaking, contamination, or adulteration. Milk in its warm condition may only be moved short distances, such as, for example, from the byre

[1] This apparatus has been employed in some cases in Britain with advantage.—*Editors of English Edition.*

to the dairy, and then it should only be in open or loosely-covered vessels, in order that it may become cooled by the cooler air, and that evaporation may take place from it without hindrance. When carried further, milk must first be cooled to 12° C., and tightly closed vessels must be used. Care must also be taken that the cooled milk does not attain on the way a temperature at which rapid fermentation may take place. If wooden vessels be used, this is not difficult to effect, since wood is a bad conductor of heat. It is more difficult to accomplish when metal vessels are used, which is necessary when milk is sent longer distances by rail.

Fig. 23.—Railway Milk Can.

In order to avoid, as far as possible, the formation of lumps of butter in the milk, through violent shaking, a light waggon is used for the conveyance of the milk, and the barrels are filled full, or if not full, carefully cleaned wooden floats are used. For the purpose of distributing the milk from one place to another in the country, large wooden vats are best, with wide openings and suitable floats. Such vats are not so quickly or so easily cleaned as metal vessels, but in other respects are preferable, inasmuch as they preserve the milk excellently from the action of external warmth, and they also last longer and are cheaper. For all other purposes, especially for the distribution of milk by rail, metal cans are most suitable, and they are easier to handle (figs. 23–25). Very useful and suitable are the conical cans, holding 36 to 77 litres (8 to 17 gallons), made of steel plates, which are used in England, although, unfortunately, they are still unknown in Germany. In Germany only cans made of white metal are used, which contain, for the most part, only 20 to 25 litres ($4\frac{1}{2}$ to 5 gallons).

28. Value of Milk for Fattening Purposes.—The use of milk for the fattening of swine is not economical, and ought only to be adopted in rare cases. On the other hand, the fattening of calves with milk is much practiced, and under favourable circumstances is attended by very good results. The treatment of fattening calves in feeding requires great attention and care, as well as skill of a special kind, which everyone does not possess. For obvious reasons, this practice

more generally prevails, and gives better results, on the smaller than on the larger farms. If, as is commonly the case, the fattening process last from eight to twelve weeks, it may be assumed that on an average 10 kilos. (22 lbs.) of milk make 1 kilo. (2·2 lbs.) of live weight. The value of the kilo. of milk must be considered with reference to the price of veal. It is well known that the flesh of calves which have been exclusively fed on fresh milk is of excellent quality, and possesses the desired yellow colour of good meat.

The fattening of swine with milk was formerly very common in some districts of the Archduchy of Oldenburg, but is now almost entirely

Fig. 24.—Top of Milk Can, with Seal and Pincers, *showing Mode of Fastening.*

Fig. 25.—Cart Milk Can.

abandoned. In the case of fattening calves it is impossible to give any definite figures of the daily amount of milk to be used. As much should be given daily as the calves care to drink, but great care should be exercised against over-feeding, and against allowing them to drink too quickly. A drink three times a day at least, with milk of a suitable temperature, is necessary. It is also necessary to keep the calves in separate boxes, in narrow byres, shaded from light, in order that they may remain as quiet as possible. The byres should always be kept clean.

29. The Value of Milk as an Article of Sale.—It is often the case that milk is not treated on the spot where it is produced, but is sold.

Before determining to sell milk, the question should be considered whether this method of utilizing it is really the most remunerative. A very simple calculation in each case will enable this question to be easily answered. A few remarks will be made on this subject in Chapter VII.

The most profitable way of disposing of milk is to the private consumer, since the price of milk in all the larger towns is almost always at a figure which can very rarely be obtained, and that only under the most favourable circumstances, when milk is churned or otherwise disposed of. The practice least to be recommended, as a rule, is that of selling the milk to small milkmen, because this method is often very inconvenient and troublesome. In order to avoid this difficulty, farmers in recent times have founded many associations for the purpose of calling into existence town dairies, which may effect the sale of milk, and in which whatever milk remains over unsold is daily worked up or churned. Such arrangements have worked very well. Through the development which has followed the extension of railways, agriculturists who live less than twenty miles distant from a town, and not too far from a railway-station, may become members of a town company, or partners in a town dairy business. In all cases in which the sale of milk is either exclusively or chiefly made for direct consumpt, the seller may be regarded as silently assuming the moral obligation to make every effort to supply all his milk unadulterated and as rich as possible.

The proper arrangements for the supplying of towns with milk, carried out in the shops of milk merchants in large milk businesses in towns, and in shops for the sale of specially prepared milk for children and invalids, can scarcely be regarded as coming within the scope of purely agricultural industries, and therefore need not be described here. The author contents himself with a few remarks regarding them.

If milk in the milk-market, which comes from small milk merchants in the towns, or from milk producers direct to the consumers, suffers in the matter of cleanliness or percentage of fat and total solids, the blame is undoubtedly with the small dealers or with the milk producer. No doubt they should not alone bear the blame of the matter, for the blame must also be shared by the great public, which patiently allows itself to be imposed on.

It is in the interests of the public good to limit as much as possible

retail business, and in a suitable way to effect a concentration of the business of milk selling.

Every large town milk business should be conducted in the same way as every large town milk association. On the one hand, the milk suppliers should be bound to pay attention to the cleanly treatment of milk, to cool the milk immediately after milking in a prescribed manner, to feed the cows in a proper way, and to give notice at once in the event of disease breaking out on the farm either in the case of persons or animals; and, on the other hand, to appoint inspectors charged with the carrying out of the regulations and the superintending of the distribution of milk from the central place. In institutions in towns where the milk treatment for invalids is practised, or in institutions for the supply of children's milk, too great care cannot be paid to cleanliness in the byre, to the animals, to the food, to milking, to the whole subsequent treatment of the milk, and especially to the health of the cows.

Up till now it has not been possible to devise precautions for preventing milk sold in the streets, from barrels in milk-carts and tapped by means of a cock, from having the cream separated by rising to the surface, and the customers from receiving milk of different values. If the milk be not removed from the barrel by means of a cock, but be removed by means of a measure, it is easy to provide every customer with milk of equal quality. Milk-cans for milk-carts have recently been patented in Germany, in which, by a special arrangement inside of the barrel, the rising of the cream of the milk during distribution is prevented. Experience has not yet demonstrated whether these cans fulfil the object aimed at, and whether they are practically useful.

30. **Milk Adulteration.**—Cows' milk may be regarded as adulterated whenever the average chemical composition differs in any way, by the addition of foreign ingredients, from the average composition of milk obtained by the continuous and perfect milking of the udder of the cow. The milk adulteration that has to be dealt with in practice consists in the watering of the milk, or in its partial creaming, or in both creaming and watering. Occasionally, but much more rarely than was at one time the case, milk is mixed with skim-milk, which produces a similar effect to a partial removal of the cream. Adulterations of any other sort are very seldom met with in practice. On the other hand, the milk trade suffers from many trickeries and intentional deceits, which are constantly being practised. For example, old milk, or milk collected from milk remnants, is palmed off as fresh milk, or skim-milk is sold for whole milk, or the seller gives false measure, and similar deceits.

According to the nature of the conditions under which, as has just been described, milk is to be regarded as adulterated, every kind of preservative used for milk must also be regarded as an adulterant. Indeed, it may be concluded that there is something of a deceitful intention in the secret use of such agents, since the buyer is under the impression that the sweet condition of the milk is the result of its fresh state, or of the careful and cleanly treatment to which it has been subjected before sale, and is thus grossly deceived.

In former times, before much experience had been obtained in the supervision of the milk trade, it was customary to draw up a formal list of adulterants said to be found in milk, as well as methods for detecting all possible and impossible adulterants, which were systematically arranged in a tabular manner. Thus, in addition to the adulterants above referred to, adulteration with albumin, white of egg, caramel, artificial emulsions, meal, gum, dextrin, glue, bird-lime, soapy water, calcium and magnesium carbonates, the pulverized brains of calves, sheep, and horses, and many other things were spoken of. The large experience which has been gained in the course of the last twenty years has shown that in Germany, at least, hardly one of the above-mentioned and highly improbable adulterants have been used. Further reference need not be made to them, since they have no general interest, and if they ever were practised would, by means of the present methods of chemical analysis, be very easily detected.

31. Milk Testing.—In consequence of the adulterations of milk described in § 30, it has to be determined, in testing milk, whether the average chemical composition of the milk has been altered, by external influences, after it has left the udder, so as to differ from that of milk furnished by continuous and perfect milking, and, in the case of any change having occurred, to discover the nature of the influence that has produced the change. In the first place, it is necessary to obtain as accurate a determination as possible of the properties of the suspected milk; in the second place, an exact knowledge of the usual average chemical composition and the usual nature of the milk obtained in that district; and thirdly, it is necessary to have an ample knowledge, gained by experience, of the limits of variation in the composition and specific gravity of milk.

Chemical analysis of all the constituents, and the determination of the specific gravity, afford the most reliable evidence of the quality of the milk. As, however, in earlier times it was only in very exceptional cases possible to conduct such an investigation, it was

necessary to form an opinion from single constituent properties of the milk. For this object a number of so-called milk-testing methods of a most varied kind were employed. In this matter practice, more shrewd than theory, adopted the determination of the specific gravity as affording the most valuable test. For a period of ten years the importance of this test was quite undervalued on account of the careless, unscientific method in which some early investigators carried it out, and it has only been re-established by later investigations. Chemists on their side recommended the determination of one or other of the milk constituents, generally the milk-fat, and, in addition to this, quite a number of other tests of milk. Many of these tests were proved to be worthless on account of a want of knowledge of their true significance, as well as because they were often based on false assumptions, due to ignorance of the true composition of milk. Owing to the advance in our knowledge of the nature of milk, made since 1876, the improvement in methods of chemical analysis, and the discovery of Soxhlet's areometric method of determining fat—which gives results as reliable as those obtained by gravimetric methods, and dispenses with the use of the chemical balance, while it is simpler and more convenient to apply,—the older methods in use have been replaced, and have now become antiquated; indeed they possess now only historic interest.

For the purpose of judging milk, it is quite immaterial whether the quantities of nitrogenous matter, milk-sugar, and mineral matter are determined separately, or all together, as "solids not fat". In the first place, we know too little with regard to the variation which these constituents—with perhaps the single exception of the mineral matter—are subject to, to form a decisive opinion based on the amount of any one of them. In the second place, the respective ratio of the three constituents is not at all, or very slightly, altered by such adulteration as is commonly met with in practice, so that it may be said to give little assistance to our judgment; and thirdly, in the case of watered milk, the diminution in the quantity of one or other of these constituents furnishes us with no truer indication than the diminution in the total quantity. At present, therefore, a full analysis is seldom made unless we have to do with some particular kind of adulteration. Instead of a full analysis, we generally determine the specific gravity at 15° C. (s), the percentage of fat (f), the percentage of total solids (t), the sum of the three

above-mentioned constituents, *i.e.* the percentage of "solids not fat" (r), and lastly the specific gravity of the total solids (m).

When it is desired to make an analysis of milk, it is of the greatest importance to obtain a true average sample, this being effected by thoroughly mixing the milk before taking the sample. In this connection, it must not be forgotten how quickly milk changes, owing to the tendency the fatty globules have to rise to the surface. Thorough mixing of the milk, therefore, before taking the sample, must never be neglected. When necessary, the milk should be warmed to 40° C. before sampling.

Especial care should be taken in the determination of the specific gravity (s), and to do so, if possible, up to the ten-thousandth figure. For this purpose a glass hydrometer, of the Soxhlet pattern, should be used, in which the divisions indicating thousandths should occupy 7·5 mms. The temperature of the milk should also be observed, and the results should be corrected, by means of correction tables, to the temperature of 15° C. if the specific gravity has not been taken at that temperature. Special attention ought to be paid to the fact, that freshly-drawn milk yields figures from $\frac{1}{2}$ to $\frac{1}{1000}$th less than the figures yielded by the same milk, even after the lapse of so short a period as three hours. On this account one can only accept the specific gravity of milk as final when the milk has stood for three hours from the time it was milked. The fat (f) is determined, either by gravimetric methods or by Soxhlet's areometric method, or with the lactocrit. If (s) and (f) have been obtained, the total solids (t) may be calculated by means of formula (3) given in § 11.

$$(1)\ t = 1{\cdot}2 \times f + 2{\cdot}665 \frac{100 \times s - 100}{s}.$$

If, from the value found for (t), the value for (f) be deducted, the value (r) (viz. the "solids not fat") is obtained:

$$(2)\ r = t - f.$$

From formula (7), given in § 11, the value of (m) (viz. the specific gravity of the total solids) can be calculated:

$$(3)\ m = \frac{}{t - \frac{100 \times s - 100}{s}}$$

This value (m) is altered by creaming the milk, but not by watering it. The knowledge of the five values, (f), (t), (s), (r), (m), is

sufficient for most cases of adulteration occurring in practice, and not only for an answer to the question as to whether milk is adulterated or not, so far as this can be answered, but also for the determination of the nature of any of the above-mentioned adulterations. Adulteration by watering is most easily seen in the values (*s*) and (*r*), since both these values in unadulterated milk of the most different origin vary between far narrower limits than the values (*f*) and (*t*), as has been already mentioned in § 10. For this reason the determination of the specific gravity of milk furnishes the most important evidence for forming an opinion on it, not only as a preliminary test, but also as a thoroughly reliable ground of final judgment.

If, for example, (*s*) equals 1·0319, and (*f*) equals 3·50 per cent, with the aid of the table, the calculation is worked out as follows:—

For (*t*) the value in the tables is $1{\cdot}2 \times f$ for 3·5 to 4·2, and the value of

$$2{\cdot}665\frac{100 \times s - 100}{s} \text{ for } 1{\cdot}0319 \text{ to } 8{\cdot}238\ 8{\cdot}24 \text{ therefore is}$$

$$\begin{array}{l} 8{\cdot}240, \\ 4{\cdot}200 \end{array}$$

$$t = 12{\cdot}440 \text{ per cent, and } r = 12{\cdot}44 - 3{\cdot}50 = 8{\cdot}94:$$

while for (*m*), by the tables, we find the value of

$$\frac{100 \times s - 100}{s} \text{ for } 1{\cdot}0319 \text{ to } 3{\cdot}091; \text{ therefore}$$

$$\begin{array}{l} 12{\cdot}440 \\ \underline{3{\cdot}091} \\ 9{\cdot}349\,)\,\underline{12{\cdot}440}\ \ (1{\cdot}33 \\ \qquad\quad \underline{3{\cdot}0910} \\ \qquad\qquad 2863 \end{array}$$

If milk with properties of this kind has been watered so that (*s*) equals 1·0248, (*f*) will be found to equal 2·72 per cent, (*t*) to equal 9·71 per cent, (*r*) to equal 6·99 per cent, and (*m*) to equal 1·33.

If, in the case of creamed and watered milk, (*s*) equals 1·0270 and (*f*) equals 1·695 per cent, (*t*) would be found to equal 9·041, (*r*) to equal 7·346, and (*m*) to equal 1·41.

By simply watering milk, the original values of (*s*), (*f*), (*t*), and (*r*) are diminished throughout; while, on the other hand, the original value of (*m*) remains unchanged, because the actual ratio of the individual constituents of the dry substance does not suffer alteration.

By creaming, the original values of (*s*) and (*m*) are increased, and to a lesser extent that of (*r*); but the original value of (*f*) is very considerably lowered, and that also of (*t*), but to a somewhat lesser extent.

If milk is both creamed and watered, and the watering has been checked by the use of the hydrometer, or if the milk is only slightly watered, the original values of (*s*) and (*r*) remain unchanged; indeed they are even slightly increased. Generally, however, the values of (*s*) and (*r*) are diminished. The original value of (*m*) is increased, while that of (*f*) is very considerably diminished, and that of (*t*) to a less extent.

The areometric estimation of fat by Soxhlet's method has been so universally adopted that it is not difficult for anyone to make himself familiar with it. Its principle is a very happy one. The fat in a measured quantity of milk is dissolved in ether, and the specific gravity of the ether solution at a certain temperature is determined in an ingeniously constructed apparatus. From this the amount of fat in the milk is calculated—the higher the specific gravity of the solution, of course the more fat does it contain. As the difference between the specific gravity of fat and ether is considerable, far more than, for example, the difference in the specific gravity of milk and water, the specific gravity of the ether is correspondingly changed by the addition of even a small quantity of fat. This renders it possible to estimate the percentage of fat in milk with very great delicacy. A greater advantage which it possesses is that it estimates, with almost an equal degree of accuracy, the percentage of fat in skim-milk as well as in whole milk.

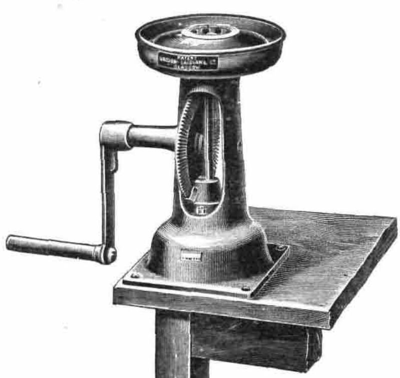


Fig. 26.—The Lactocrit.

In the case of the lactocrit (fig. 26), the coagulated portion of the nitrogenous matter in a measured quantity of the milk, precipitated by continuous boiling of the milk with a mixture of glacial acetic acid and sulphuric acid, is first completely dissolved, and the fatty milk-globules,

which have been melted at the necessary temperature, thoroughly incorporated with each other, are enclosed in test-tubes, and subjected to centrifugal force in the lactocrit. The percentage of fat is estimated by the observed volume of melted fat. Originally this method was only utilized in the investigation of whole milk. Subsequently, in 1890, the mixture of acids was replaced by a quantity of ethylidene-lactic acid and solution of hydrochloric acid, which perfectly dissolved the nitrogenous matter in the milk, without attacking the fat to any extent. The result was a great improvement, both in accuracy and convenience, in determining the fat, and a more extensive application of the method ensued. It enables a determination of fat to be made in skim-milk and butter-milk, as well as whole milk, if not directly, yet with great accuracy.

In the method devised by Marchand de Fécamp, which was investigated and improved in 1878 by Schmidt and Tollens, the milk is treated in a lacto-butyrometer with alcohol, ether, and a little potash. The fat is dissolved and almost entirely separated in the surface layer of the ether. From the volume of this layer the percentage of fat is calculated by means of a table.

A fact which militates against the Marchand method is the retention, in the lacto-butyrometer, in a dissolved condition, of a certain proportion of fat. This amount, although generally the same, may vary under certain conditions. In this method, therefore, conditions have to be reckoned with which are not perfectly under control. All the improvements made up to the present time in this process affect only the details, such as greater convenience in working it, more exact methods of reading the degree, &c., and do not affect the accuracy of the process. With milk containing from 3 to 3½ per cent of fat this method gives good results, the variations from gravimetric methods being generally less than ·2 per cent. It is well suited for practical use in agriculture generally, and is useful, for many purposes, in large dairies. For scientific work, however, or for legal purposes, and for the determination of the commercial value of milk, it is not sufficiently accurate to be relied upon. It cannot be used for solutions containing more than 1·339 per cent of fat. The methods for fat determination already described, and more especially the Soxhlet and lactocrit, are thoroughly accurate, delicate, and reliable scientific processes.

Where it is impossible to estimate the percentage of fat, and the above methods of milk-testing are consequently inapplicable, a milk-test devised by Müller may be found to serve the purpose. The specific gravity at 15° C. is determined, and the milk is allowed to stand for 24 hours in a Chevalier cremometer at a temperature

as near 15° C. as can be obtained. The depth of the cream layer is noted for the purpose of calculating its percentage volume, after which it is removed. The specific gravity of the skim-milk at 15° C. is then determined, so that it may be seen whether it remains within the usual limits. This method has been found extremely useful for testing milk suspected of having been creamed and watered, especially in hilly districts, where the conditions of milk production do not exhibit such wide variations as are often found in some districts of flat lands.

The "byre-test" furnishes a complement to this formerly largely-used method of milk-testing.

The byre-test is carried out in the following manner. If, on investigation, a sample of milk of known origin is found to yield unusual results, the byre is visited as soon as possible and the milk investigated. The results thus obtained are compared with the previous ones, so that it may be ascertained whether the earlier results are confirmed. Where the results of the byre-test are to be given as evidence in a court of justice, the test must be carried out in the presence of witnesses, and care should be taken that the cows are thoroughly milked. It is advisable, therefore, that a skilled milker should be employed, or that the operation should be carried out under his directions and to his satisfaction. The quicker the byre-test follows upon the seizure of the sample of milk, the more valuable are its results for purposes of proof. The same milking-time as that at which the suspected sample was obtained should be chosen, as well as the same cows which have been milked, and the test, if possible, should be applied within 24 hours, and in no case should more than three days be allowed to elapse. It is necessary generally to submit the milk coming from the whole of the cows in question to investigation. In this way the milk of each single cow can be tested. If no important change in the feeding and treatment of the cows have taken place in the interval between the time of the milking of the suspected sample and the milking of the sample taken for the byre-test, then the duplicate results, in the absence of adulteration, should show a variation of not more than a two-thousandth in specific gravity, equivalent to a difference in fat of not more than ·3 per cent, and a difference in the total solids of not more than 1 per cent. Where larger variations than the above are found, then the suspicion of adulteration is confirmed, and in some cases may be absolutely proved. Caution must always be exercised, however, since it has been noticed occasionally—in very few cases, it is true—that the specific gravity of the milk of single cows has shown a difference, from day to day, of several thousandths, indeed, as many as six, and a difference in the

percentage of fat of from 2·5 to 3 per cent. As a result of the author's own experience, he has found that the byre-test is only valuable where two milkings per day are generally practised, and where the conditions of milking in all the byres from which the milk is collected are essentially similar, as is the case, for example, in many districts of Switzerland, Austria, and the hilly districts of South Germany. As far as North Germany and the middle districts of Germany are concerned, where the conditions vary greatly in the different byres, it is absolutely worthless.

For the detection of the less common adulterants of milk, such as the presence of poisons, or the identification of bacteria, it is obviously impossible in this work to give a more detailed description of the mode of investigation which must be adopted.

In the case of the milk of single cows, the question as to whether it is adulterated or not is a most difficult one to decide. With market milk, however, which almost invariably represents the milk of a number of cows, it is not so difficult; while in cases where the milk of the larger herds is concerned, the detection of adulteration is rendered much easier. The fixing of standards by which the purity of milk should be determined is almost impossible. We shall, at any rate, not attempt to lay down any limits of composition to which the unadulterated milk of single cows is subject. Such figures would not be of any assistance in forming a judgment. The following figures which the author quotes, and which apply to market milk, in which the variations found in the milk of single cows are neutralized, are therefore to be used with very great caution. In the majority of cases of German milk, produced under ordinary conditions, the following figures may be taken as showing the variations in its composition:—

Specific gravity at 15° C. a variation from 1·029 to 1·033.

Fat, ...	2·50 per cent to	4·50 per cent.
Total solids, ...	10·50 " "	14·20 "
Solids not fat, ...	8 " "	10 "

The specific gravity of the total solids should not exceed 1·400.

It must be strongly emphasized that the above figures, which apply to market milk, must not, in any case, be held as applying universally; but they may be found to hold fairly well in the majority of cases. In different districts of Germany, however, they must, in one or other of the particulars, be departed from. Also, it

must not be assumed that milk which differs in composition from the above-stated figures is consequently adulterated, but merely that milk, in which this is the case, possesses unusual properties, which warrant suspicion, and justify further testing for its purity. It can also hardly be contended that the occasional variation of milk from any one of the above figures points to adulteration. Adulteration on a small scale is, as a rule, impossible to detect in milk.

The opinion of anyone with regard to the genuineness of a sample of milk, who has not taken the precaution, during a year at least, of making himself familiar with the conditions of treatment and the properties of milk, in the districts where the milk-tests are carried out, and who has not performed a very large number of milk analyses, is not worthy of regard. The same may be said also of anyone who neglects to take into consideration a proper study of the action of all the influences which affect the secretion of milk.

We have already considered the nature and properties of cows' milk, and of the influence which interrupted milking of the cows, or incomplete milking (not milking dry), or of milking at irregular intervals, exercises on the composition of milk. The variations which the composition of milk from day to day and from milking-time to milking-time exhibits, in short, all the influences which affect the secretion of milk, and which have to be taken into careful consideration in the testing of milk, have already been treated in Chapter I.

32. The Supervision of the Milk-trade in Towns.—This has to do, in the first place, with the discovery of the sellers of suspected samples of milk, and, in the second place, with the discovery of how and in what manner the milk has been adulterated. The police supervision of the milk-trade in towns is consequently of a double character, viz. the preliminary testing at the place of sale, and the formation of a final judgment by an experienced and skilled analyst. Careful observations should be constantly—if possible daily—instituted at the places of sale, and the appearance, smell, flavour, and reaction of the milk should be tested. The specific gravity should be taken with a correct hydrometer, and an observation of the temperature of the milk also made. A determination of the percentage of fat, by means of a lactoscope, should perhaps also be made. It should also be noted whether the capacities of the milk-vessels are

of the proper standards, and if the measures of the seller are correct and properly stamped. In the supervision of places for the sale of milk, only practised and experienced men should be employed. When it has been thoroughly mixed, an average sample of the milk is taken and transferred to the specially-prepared bottle, which is corked and sealed. This should be accompanied, if possible, by exact details furnished by the seller as to the source of the milk. The examination described in paragraph 31 should then be carried out.

The rough practice of many under-officials, charged with the arbitrary power of directing that all milk which does not come up to the standards of purity should be poured into the sewers, is unworthy of the present time. It is, in short, destroying a food which has only been partly robbed of its nutritive properties.

Supervision of the milk-trade in towns, which limits itself to the prevention of fraud and gross adulteration, can only be said to be fulfilling half its functions. There are other duties which it ought to perform in the protection of the community, and in the furtherance of general health—duties which may be described as even higher and more important. It should see:

(1) That the milk exposed for sale is not only unadulterated, but that it is of such a quality as is obtained by the perfect milking and thorough admixture of the entire milking of a single cow, or of the milk of several cows.

If, in the case of large quantities of milk, thorough mixing does not take place before it is separated into the sale cans, it is quite impossible that the percentage of fat in the contents of the single milk-cans should be the same. Milk sold under such conditions favours one customer at the expense of another.

(2) It is desirable that, for the purposes of cooking and churning, the milk should possess the ordinary (normal) properties of good milk, and should be devoid of abnormal properties.

Milk with any uncommon properties, such as, for example, colostrum milk, milk showing any of the milk-faults, milk containing coagulated masses or lumps of butter, milk which exhibits unusual behaviour when treated with rennet or when boiled, and milk which shows an unusual bluish-white colour, or a strange smell or taste, should never be allowed to come to the market.

(3) Only sweet milk, which remains unchanged at ordinary temperatures, for some time after sale, without becoming coagulated, and which stands boiling, should be provided.

(4) The milk should be worth its price, that is to say, it should have the average percentage of total solids and fat, found in the milk which is obtained in the respective districts, from properly-fed and well-tended cows.

(5) Only milk which comes from healthy cows, free from foreign ingredients, and uncontaminated with pathogenic germs, should be sold.

The milk of cows which have had fever, or have been treated internally or externally with medicines, is unsuitable for sale. Care ought also to be taken that the milk is kept clear of contact with people suffering from infectious diseases, or people having charge of such persons.

The stringent demands which we are justified in making at present on the milk-trade, and which in some places are beginning to be timorously enforced, will become more easily and more perfectly *granted the more the milk-trade is concentrated. The supervision* of the sale of milk is uncommonly difficult in towns in which the sale of half-milk, that is, a mixture of creamed evening milk with whole morning milk, is practised.

In addition to milk, cream, skim-milk, butter-milk, and whey are sold in commerce.

Cream, as it is usually sold, contains from 11 to 25 per cent of fat; but the want of definite regulations concerning its sale has never been felt. The same may be said with regard to butter-milk and whey, which only come into the market in small quantities. With regard to the supervision of the trade in skim-milk, where it is desired, the tests should be limited to its appearance, smell, and flavour, and to ascertain whether it stands boiling, and is free from unusual properties. The determination of the specific gravity (which in the case of skim-milk obtained from *centrifugal machines generally containing not more than ·5 per cent of fat,* varies between 1·0335 and 1·0360) will reveal the addition of any large quantity of water. Since the high value which skim-milk possesses as a nutritive food depends entirely on its percentage of albuminous matter, it *is quite immaterial whether it contains a tenth of a per cent of fat more* or less; and for this reason it is quite wrong to prevent its sale unless it has been proved to contain a certain percentage of fat.

The analysis and testing of skim-milk is carried out very much

in the same way as that of sweet-milk. Further details will be given in Chapter III.

33. The Supervision of Milk in large Collecting and Co-operative Dairies.—In the interests of the milk trade, it is necessary that the milk coming from each separate dairy should have its appearance, taste, and smell tested. Its temperature should also be taken, in order to see if it has sufficiently cooled down after milking. It is further necessary to ascertain whether it has been contaminated with dirt, to determine its specific gravity, and to see that the vessels used for carrying it are suited for the purpose. The milk should be tested by boiling it, and a preliminary estimation of its fat should be made. If the milk from any dairy appears suspicious, an average sample should be taken, with all due precautions, before witnesses, and sent for accurate analysis to the nearest public chemical laboratory. At the same time, in order to hinder as much as possible any fermentation during transit, the milk should be cooled in ice before being sent away, and every endeavour should be made to hasten the transit. Since the conditions of clear profit are greater the richer the milk is in fat, the managers of dairies should make a point of discovering those suppliers who send in unusually poor milk, and they should either cease dealing with them, or should induce them to increase gradually the percentage of fat in their milk. The best way of avoiding the imposition which is daily practised, when milk of varying value is simply sold according to weight, consists in buying it from producers at so much per kilogram according to the percentage of fat it contains, in short, in selling it according to the percentage of fat it contains as well as according to its weight.

In order to carry out this method of purchase, it is necessary that the milk obtained from each supplier be regularly tested by some method or other for its percentage of fat. If such tests are not made often enough, it can hardly be expected that reliable data will be available for ascertaining what the true average percentage of fat of single milk consignments really is, for it is not impossible that, in the case of an incorrect average being taken, the payment for milk may be as far, or even further, from being a just one than is the case in buying milk of varying value simply by weight; and thus all the trouble and expense involved be really of no use. To obtain reliable data the milk of each customer should be examined at least once a week.

If in any district—and in Germany there are many such districts—

the external conditions under which milk is obtained are similar, and the single consignments of milk differ comparatively little in their relative percentages of fat, it is not worth the trouble of introducing this costly and inconvenient method of milk valuation.

If all parties are agreeable, the lacto-butyrometer may be used for investigating the milk. The Soxhlet method, however, is by far the better one. Where it is impossible to overtake the number of milk investigations that are required to be made by this method, the lactocrit may be used. This process, even where a large number of investigations have to be made, is not likely to give unreliable results. According to the author's experience, where the number of fat determinations amounts to 30 per week, or to 15 determinations twice a week, it is almost as cheap,—despite the high price of the apparatus—as the Soxhlet method; and where the number of determinations exceeds this, the cheaper, proportionately, does it become. One worker, provided he is supplied with assistance in the cleaning of the apparatus, &c., can easily undertake the determination of fat in more than 100 samples of milk daily, and in over 600 samples in a week. The indirect determination of the percentage of fat in milk by means of the thickness of the cream layer, as, for example, by the Fjord milk-control apparatus, is now quite antiquated, especially for the purpose here referred to.

With regard to the method of fixing the price per kilogram of milk, according to the percentage of fat it contains, reference will be made in § 145.

In dairies in which cream cheeses are made out of the milk obtained from different dairies, where any difficulty may occur, the so-called milk-ferment test and the rennet test are useful.

For the carrying out of the milk-ferment test special apparatus is required. The improved milk-ferment apparatus of Walter, or that of Denkelman, known as the lacto-fermentator, for example, may be used. In the application of this test, the milk of each milk-supplier is set in small quantities, in suitable vessels, for some time (12 hours) at a temperature of 40° C. At this temperature the action of injurious low ferments which may be present is developed more quickly than at the ordinary temperature. Pure milk, under the above conditions, coagulates into a cohesive homogeneous mass, resembling the albumin of a boiled egg, and possessing a pure acid smell. If the milk in any of the vessels has not become coagulated, or presents a ragged, flocculent coagulation, floating in a muddy serum, or occurs in non-homogeneous slimy clots, full of gas-bubbles, and possesses, instead of the purely acid smell, a strange, unpleasant odour, it is to be inferred that the milk which this sample represents is

likely to impair the quality of the cheese. If, on repetition of the experiment within the next few days, similar results are obtained, and if the quality of the cheese is unimpaired so long as this questionable milk is excluded, it is quite justifiable to hold the supplier of the contaminated milk responsible for any damage that may have arisen.

Just in the same way as the milk-ferment test renders it possible to trace milk contaminated with deleterious fungoid growths, the rennet test renders it possible to detect milk which possesses unusual properties, and which would exert a deleterious action in cheese-making. The rennet test is applied in the same way as is done in testing the strength of rennet, and consists in treating with rennet the milk which is being investigated, and observing whether it coagulates quickly or slowly, or whether it coagulates at all, and whether the coagulated mass obtained possesses the ordinary properties.

34. **The Supervision of the Production and Manufacture of Milk.** —In the supervision of milk production in country districts, all that can be done is to take care that the cows are fed as suitably and richly as circumstances permit, and that regular tests of the milk are made as above described. This object will be attained if similar quantities of butter are made from equal quantities of milk obtained from a mixed herd of cows. As this is not always the case, and as the average percentage of fat in the milk of cows differs very much according to their surroundings, attention must be paid not only to the yearly quantity yielded by each cow, but also to the quality of the milk, in order to utilize the most valuable cows for breeding purposes. Those that yield a less satisfactory return ought to be removed, and in this way it will be possible gradually to increase the yield of the entire herd. If sufficient attention has not hitherto been paid to the quality of the milk, the neglect has been chiefly due to the fact that a correct method for the determination of the percentage of fat, which could be carried out at once rapidly and easily, and which was at the same time accurate and reliable, was awanting. The Foser Lactoscope, formerly recommended for this purpose, no longer satisfies present demands. Since the lactocrit has been devised, however, and has been proved to be as handy as it is reliable, a regular testing of the milk of single cows for its percentage of fat, especially in large herds, is no longer so very difficult to carry out. It is to be hoped that a reliable method of determining fat will soon be discovered, so convenient and at the same time so cheap that it may be capable of being

employed on small farms. A wide field of activity still remains in Germany, which has hardly yet been entered upon, for efforts for the purpose of increasing the milk yields and the capacities of cows, in which amply repaying success and a rich return for the money, time, and trouble spent, can be safely promised.

Perhaps it may be also necessary to pay attention to the adaptation of the calving-time of cows, in the most advantageous manner, to the different agricultural conditions, to the intermittent yield of the cows, and to the recurrent variations in price that commonly occur throughout the year. In general, these conditions have hitherto received too little attention.

In the supervision of the utilization of milk, the first duty is to strictly maintain the most absolute cleanliness in the byre, in the milking of cows, and in the treatment of milk. Care should also be taken that milk-cows are well treated, and are thoroughly milked at each milking, and that the milk of diseased cows, or milk exhibiting any unusual properties, should not be utilized, and that the milk should not come into contact with sick persons. In dairying, only careful, capable adult dairymen should be employed, and the arrangements should be such that every operation should go on smoothly, and that every precaution adopted should be effectively carried out. A simple tabular list of instructions of dairy and technical details, which should include hints on branches of the business of dairying, should, without fail, be put on the walls of byres and dairies. Finally, it is to be recommended that samples of milk, skim-milk, and butter-milk should from time to time, if no other method offers, be sent to a research station to be tested for the percentage of fat, in order that the dairyman should be in a position to judge whether the yield of butter corresponds to the percentage of fat, and if not, to what extent it is deficient.

35. The Analysis of Milk.—It is not difficult to make one's self familiar with Soxhlet's widely used apparatus for the determination of the percentage of fat in milk, or with the working of the lacto-butyrometer and the lactocrit. Opportunities for this purpose are easily obtained. Opportunities for becoming acquainted with the method of carrying out the full analysis of milk occur less frequently. The detailed description of the nature and properties of milk given in earlier paragraphs must have excited a desire to obtain at least a description of the methods which render it possible to determine the single constituents of milk, and to estimate their

percentage. Chiefly for the purpose of satisfying this desire, a short description is given in what follows of how an analysis of milk is made.

Before proceeding to the analysis, the milk is tested in respect of its appearance, smell, taste, and reaction. Its specific gravity is taken at 15° C., and it is tested by boiling. The action of rennet on it is also tested and its percentage of cream estimated by allowing it to stand for 24 hours at from 12° to 18° C. in a Chevalier cremometer. Further, it is desirable, where possible, to obtain information as to whether the milk is from one cow or from several, whether milking is carried on in the byre from which it has come, twice a day or oftener, and from which milking the milk comes. Particulars with regard to breed, treatment, feeding, age, length of time after calving, general health of the cow, and the method in which the sample has been taken, so as to decide whether the analysis represents correctly the composition of a milk such as should have been obtained under these conditions, should also be obtained.

When a sample of milk is drawn for analysis, the milk should not only be thoroughly mixed, but should also be brought always to the same temperature, for example, 15° C.

Determination of the Percentage of Water, or of Total Solids.—Into a thin porcelain basin is placed 15 grams of washed, ignited sea-sand which has been treated with hydrochloric acid. The basin with the sand is dried at 100° C. till the weight is constant. It is then removed to a desiccator, and, after being cooled, is weighed. About 30 c.c. of milk are then poured into a clean small beaker of about 40 c.c. capacity, and a small glass stirrer which does not reach above the lip of the beaker is added. The beaker is covered with a watch-glass and weighed. After removing the watch-glass and stirring the milk with the stirrer about 10 c.c. of the milk are poured over the weighed sand in the porcelain vessel, the watch-glass is again replaced and the beaker weighed. The difference between the two weighings gives the weight of the milk used. This is added to the weight of the vessel containing the sand. Drying is first carried on in the water-bath; the porcelain basin with its contents is then introduced into the drying-bath and dried for 45 minutes at 100° C., and then for 15 minutes at 105° C., cooled in the desiccator and weighed. It is then introduced into the drying-oven for 30 minutes at 100° C., again cooled in the desiccator, and again weighed. This is repeated until two successive weighings show no greater difference than 1·5 mg. The loss in weight, subtracted from the original weight, represents the weight of the water driven off, and by subtracting this from the weight of the milk used, the weight of the total solids is obtained.

If in the same sample of milk two determinations of the total solids be carried out, it is quite possible that, despite the greatest care, a difference of plus or minus ·15 per cent may be obtained. This difference may be chiefly ascribed to the peculiar behaviour of the dissolved milk-sugar when being dried, as has been already described in paragraph 7. The experimental errors in the determinations of the total solids may therefore amount to plus or minus ·15 per cent.

If the exact percentage of fat and the specific gravity of milk be obtained, the percentage of total solids can be calculated from the formula given in § 11. The correctness of this determination is as great or greater than the indirect determination, and can be used in corroboration.

Determination of the Percentage of Fat.—For this purpose the residue obtained in the determination of the total solids can be utilized. It is better, however, to weigh out 10 to 12 grams of milk in the way previously described, using a roomy porcelain dish, about 10 centimetres in diameter, with as much sand as will perfectly absorb the milk, and then to place this on the water-bath. In order to prevent the milk from sticking firmly to the porcelain basin, it should be stirred with a small sharp-edged glass stirrer. As soon as the mass shows a tendency to become cohesive, the whole should be stirred and all the little lumps broken up before they become hard, so that eventually one obtains a uniform coarse powder. If this does not become baked to the slightest extent after remaining 15 minutes undisturbed in the water-bath, it is rubbed with a small porcelain pestle, which is allowed to stand in the middle of the basin. It is retained 15 minutes longer in the water-bath; the powder is then carefully removed, every single particle being cleared from the vessel on to a Swedish filter-paper which contains no fat, shaped in the form of a cylinder, and resting on glazed paper. It is then introduced into the tube of a Soxhlet fat-extraction apparatus. The paper cylinder is made by wrapping a piece of filter-paper cut at right angles twice round a wooden cylinder, the diameter of which is about 4 mm. less than the diameter of the extraction tube, and then placing on the level surface of the wooden cylinder a piece of paper of similar diameter to the roll, bending this, and smoothing down the surface as one would close a packet. It is unnecessary to use a plug of cotton wool under the coil in the extraction apparatus. It is better to place some cotton wool, free from fat, above the coil, to prevent any washing out of the powder by the falling drops of the ether. In order to prevent the opening of the syphon at the base of the extraction cylinder from being closed by the coil, a ring made out of a strip of pure tin 3 to 4 mm. broad is used. The upper surface of the cylinder should be at least 3 mm. under the highest point of the syphon bend of the extraction

apparatus. Care must be taken that the coil should not be filled with cotton wool to its highest surface, and that the ether which comes from the condenser attached to the apparatus when the extraction is going on should always drop in the middle of the coil. After the coil is placed in the extraction apparatus, a wide-necked weighed flask containing 25 c.c. of pure ether is attached to the lower end of the extraction apparatus. The porcelain dish which has been used, along with the glass stirrer and pestle which have been used, are repeatedly rinsed out with ether, which is then poured on to the coil in the extraction apparatus. Sufficient ether is then added to the extraction apparatus till the syphon is almost full, a condenser is then fixed on above, the wide-necked flask placed in a sand-bath, the temperature of which is maintained at about 60° C., and the extraction is started. As a rule, it is ended in about three hours. Whether this is long enough, or whether the extraction requires to be continued for a longer period, can be proved by the watch-glass test. After the extraction has been finished the flask is taken off, and after the ether has been slowly distilled it is placed in the drying-bath, dried for 45 minutes at 100° C., and then for 15 minutes at a temperature of from 105° to 110° C., cooled in the desiccator, and weighed. The flask is again introduced into the drying-bath, dried for 30 minutes at 100° C., allowed to cool, and weighed again; and this is repeated until the two last weighings are found to show no greater difference than 1 milligram. Nearly always from 60 to 90 minutes is sufficient to effect thorough drying. If the fat has to be determined in skim-milk, sea sand is not used, but gypsum. A larger quantity of this is used than is necessary to absorb the liquid, and the extraction lasts for at least four hours before the watch-glass test is applied for the first time. The limits of experimental error for milk may be stated at, for whole milk, plus or minus, ·05 per cent, for skim-milk, plus or minus, ·03 per cent. The determination of the fat by the Soxhlet method gives equally exact results. The extraction apparatus must be firmly connected with the fat flask, and the condenser to the apparatus. The three pieces of apparatus should not be attached to each other with cork.

A much simpler method, and perhaps even a more accurate one in its results, for the estimation of fat, is Adams' process, in which the milk is dried on blotting-paper.

A coil of filter-paper, 56 cm. long, and 6·5 cm. broad, which has been previously treated with ether to remove any trace of fat it may contain, is allowed to absorb from 8 to 10 grams of milk, weighed out from a beaker by difference as above described. After a few minutes, and when the milk has thoroughly soaked in, the coil is hung on to a peg in the drying-bath and allowed to dry for an hour at 97° to 98° C. The coil is

then placed in the extraction apparatus and extracted for three hours, and the weight of the fat extracted is estimated. If the roll after extraction is once more dried for half an hour and is weighed, and the original weight of the strip of paper is subtracted from the weight thus found, the weight of the non-fatty solids is obtained. The sum of the non-fatty solids and the fat gives further the total solids.

Determination of Percentage of Nitrogenous Matter.—This is carried out according to the method recommended by Ritthausen, which is as follows:—25 c.c. of milk are measured off, weighed, and diluted with 400 c.c. of water. 10 c.c. of a copper sulphate solution (69·28 grams of pure salt per litre) are added, and then 6·5 to 7·5 c.c. of a potash solution of such a strength that 1 volume of copper is precipitated for each volume of the copper solution. The solution, after addition of the alkali, must be neutralized with acid till it possesses a weak acid reaction, and may contain a little copper in solution. The precipitate falls down rapidly, so that the supernatant liquid can be quickly filtered through a dried weighed filter, and the precipitate quickly washed by decantation and brought on to the filter. The filtrate, along with the washing water, can be used for the determination of milk-sugar; and the copper precipitate, which, in addition to the entire mass of nitrogenous or proteid matter combined with the copper, contains also all the fat which is in the milk, may be used for the quantitative determination of the fat. In any case the fat has to be extracted from the precipitate. For this purpose it is washed with a small quantity of absolute alcohol, any particles of the precipitate adhering to the filter being carefully removed with a platinum spatula, and broken up as much as possible and extracted with ether, either on a glass funnel or in the Soxhlet fat-extraction apparatus. If a quantitative determination of the fat is desired, the alcohol and ether washings may be evaporated and the residue weighed. The precipitate from which the fat has been extracted is still further treated with absolute alcohol, and is dried immediately afterwards until it becomes of a bright blue earthy colour, and easily friable. It is then placed in the drying-bath at 125° C. until its weight is constant. As soon as the weight is constant it is carefully ignited, at first at a low heat, so that the easily combustible proteid substances in combination are entirely burnt off. From the loss in weight the amount of albuminoids contained in the milk is estimated. This estimation is liable to a small error (about ·08 per cent), and is by that amount too low, since in the ignition residue the sulphuric acid formed by the oxidation of the sulphur of the albuminoids is estimated with it. It is necessary to examine the ignition residue for its percentage of carbon, and if any is found, to weigh it in a weighed filter-paper, and to calculate it to the loss on incineration, which represents the proteid substances.

If it be desired to estimate the casein by itself, 25 grams of milk are diluted with eleven times their volume of water, carefully precipitated with acetic acid, and the precipitate collected on a dried and weighed filter. The precipitate is washed, extracted from fat, and dried at 110° C., till the weight is constant. It is then burned, and the weight of the ash deducted from the first obtained weight. According to the method of J. Lehmann, the casein may be determined by the application of porous clay plates. The albumin is estimated by heating filtrate and wash-water got in the determination of the casein to boiling temperature. The clot thus obtained is collected on a dried and weighed filter, washed, extracted from fat, and dried to a constant weight at 110° C., and the weight of the ash obtained after burning is deducted from the weight thus obtained. The percentage of so-called lacto-protein may be estimated in the filtrate and wash-water from the determination of the albumin by means of the method of Ritthausen, by using copper sulphate and potassium hydrate.

Determination of Milk-sugar.—The determination of the milk-sugar, if not effected by means of the polariscope, is best carried out according to Soxhlet's method. 25 c.c. of milk are weighed out, and diluted with 400 c.c. of water, then first treated with 10 c.c. of sulphate of copper solution (69·28 grams of copper sulphate per litre of water), then with 6·5 to 7·5 c.c. of potash solution of such a strength that one volume of copper is precipitated for every volume of the copper solution. After the addition of the alkali, the solution must be neutralized and rendered slightly acid, and may contain a little copper in solution. It is then made up to 500 c.c. and filtered through a dry folded filter. 100 c.c. of the filtrate is treated with 50 c.c. of Fehling solution in a beaker, which is then covered and brought to the boil over a double wire gauze. After it has been boiled for six minutes it is filtered through asbestos, and the reduction of the copper takes place spontaneously in the asbestos tube. A small straight calcium chloride tube (about 12 centim. long and 1·3 centim. wide), whose bulb is half protected by oblique and not too soft asbestos filaments, is washed, then dried over the naked flame while air is drawn through, weighed, and attached to a filter pump. Filtration is then carried on by pouring through an attached glass funnel in the presence of a weak diluted atmosphere, then washing with water, and, after the filter pump has been detached, twice with absolute alcohol and twice with ether. Thereafter the filter tube is removed, stretched, and, after the ether has been for the most part expelled by air, bent on a holder downwards, its upper wide opening connected with a Kipp hydrogen apparatus, then the copper suboxide very carefully heated over a small flame, the top of which is about 5 centimetres under the bulb. The reduction is complete in about two or three minutes. After the asbestos tube has been cooled in a stream of

hydrogen, air is drawn through and it is weighed. If, after weighing, the metallic copper is dissolved in dilute nitric acid, the tube, after being washed out and dried, but reduced 10 to 15 mg. in weight, may be used again. The estimation of the milk-sugar from the weight of the copper, after Soxhlet:—

392·7	mg.	copper	represent	300	mg.	milk-sugar.
363·6	,,	,,	,,	275	,,	,,
333·0	,,	,,	,,	250	,,	,,
300·8	,,	,,	,,	225	,,	,,
269·6	,,	,,	,,	200	,,	,,
237·5	,,	,,	,,	175	,,	,,
204·0	,,	,,	,,	150	,,	,,
171·4	,,	,,	,,	125	,,	,,
138·3	,,	,,	,,	100	,,	,,

For example, if the copper found weighs ·291 grams, according to the table this shows

$$\frac{225 \times \cdot 291}{300 \cdot 8} = \cdot 2177$$

grams of milk-sugar in 5 c.c., that is, 4·354 grams in 100 c.c. of milk, or, if 100 c.c. of milk weigh 103·1 grams, 4·223 per cent of milk-sugar.

The filtrate which is obtained in the Ritthausen process as above described in the determination of the proteid substances may be used for the determination of the milk-sugar.

Determination of the Ash.—25 grams of milk, after the addition of a few drops of acetic acid, are heated to hard dryness on the water-bath in a platinum capsule, and then slowly incinerated over an open flame. The residue, after being boiled several times with water, is burned to a white ash. The platinum capsule is then placed in a water-bath, the watery extract slowly added, evaporated, and then slowly ignited, allowed to cool, and weighed. If milk samples which have been already weighed out for investigation are not immediately analysed, care must be taken that they are kept at a temperature under 12° C., and for only about 48 hours. If the samples are kept longer or are placed in a higher temperature, considerable loss in the total solids may be expected.

In addition to what has been above described, we may add one or two details with regard to points which may crop up in the testing of milk. In the year 1883, Uffelmann suggested that since ordinary spring and river water almost always contained ammonia, nitric acid, or nitrates, bodies which are never found in uncontaminated milk, these might be taken as an indication of the addition of small quantities of river water to milk. Unfortunately, however, the proof of the addition of water to milk through the diphenylamine reaction of nitrates and nitric acid is not of

such a nature as to permit of its practical application in milk-testing. Nor would this test be very valuable in view of the many adulterations which it would fail to detect.

The proof of the addition of carbonates or alkali bicarbonates is most easily obtained by incinerating 300 to 500 grams of milk, and determining the percentage of carbonic acid in the ash. The ash of unadulterated milk does not contain more than 2 per cent of carbonic acid; while anhydrous carbonate of soda contains 41·5 per cent. If the percentage of carbonic acid in milk exceeds 2 per cent, this may be regarded as a certain indication that an alkaline carbonate has been added to the milk. Even an addition of 1·5 grams of anhydrous soda to a litre of milk imparts to it a distinct soapy taste. In Hilger's process 50 c.c. of the milk are diluted with five times the quantity of water, coagulated with a small quantity of alcohol, and filtered. If the filtrate be evaporated to half its bulk, an alkaline reaction indicates the presence of an alkaline carbonate.

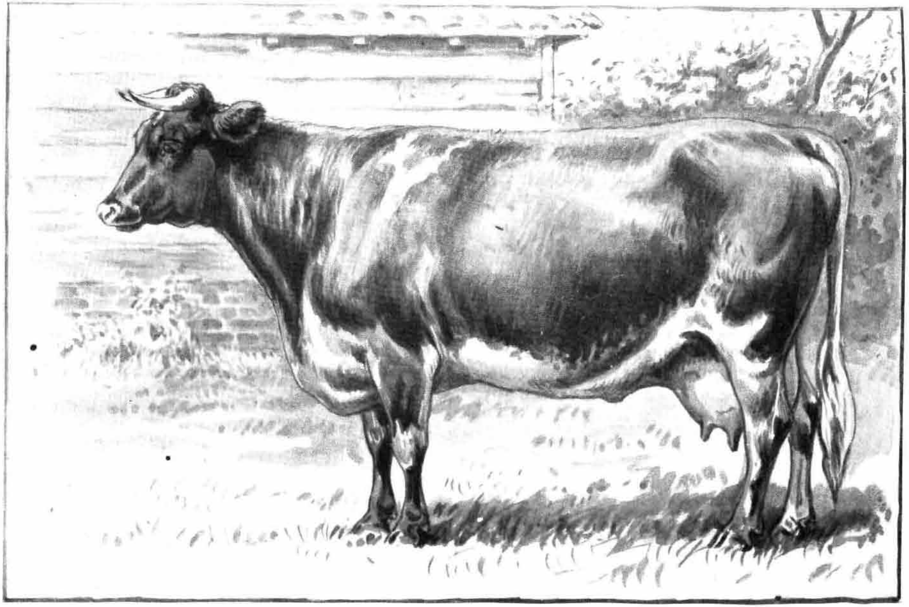
The presence of salicylic acid in milk is best detected by Pellet's method. 100 c.c. of the milk to be investigated, 100 c.c. of water at 60° C., five drops of acetic acid, and five drops of a solution of mercury oxide in nitric acid are mixed together, shaken, and after the albumin has been coagulated the mass is filtered. The clear filtrate is then shaken with 50 c.c. of ether. After the ether has separated out it is removed, placed in a clean vessel, diluted, the residue dissolved in a few drops of water, and tested to see if it will give, on the addition of two drops of a 1-per-cent solution of iron perchloride, a violet coloration. If it shows a coloration, its amount can be determined by comparing the depth of colour produced with a standard solution of salicylic acid and iron perchloride. The amount of salicylic acid can in this way be approximately determined.

In order to test the quantity of boracic acid in milk, Meissl recommends the following process:—100 c.c. of milk are rendered alkaline with milk of lime, evaporated, and incinerated. The ash is dissolved in the least possible amount of concentrated hydrochloric acid, the carbon is filtered off, and the filtrate is evaporated to dryness, the hydrochloric acid being in this way completely driven off. A small quantity of a very dilute solution of hydrochloric acid is then used to damp the ash. The crystalline mass is then treated with kirkuma (a tincture of turmeric, prepared according to Fresenius, *Qualitative Analysis*, 14th Edition, p. 90) and dried in the water-bath. In the presence of even very small quantities of boracic acid the dry substance exhibits a colour from cinnabar to a cherry-red. The reaction is so delicate that even ·001 to ·002 per cent of boracic acid can be easily detected in milk. An exact quantitative determination of boracic acid in milk is not possible. The amount present can, however, be

approximately estimated if the addition is so considerable that the percentage of ash in the milk is increased above its ordinary amount.

Small quantities of benzoic acid are most easily and most certainly detected by the following test (Meissl):—250 to 500 c.c. of milk are rendered alkaline by the addition of a few drops of lime or baryta water, evaporated down to about a fourth of its volume, stirred into a paste with gypsum powder, pumice-stone powder, or sand, and then dried on the water-bath. If condensed milk is to be investigated, 100 to 150 grams of the milk may be treated directly with gypsum and a few drops of baryta-water. The dry mass is then powdered, moistened with dilute sulphuric acid, treated four times in the cold with about twice its volume of a 50-per-cent alcohol solution, which easily dissolves benzoic acid, and which has little or no action on fat. The alcohol washings, which show an acid reaction, and which contain in addition to benzoic acid, milk-sugar and inorganic salts, are then mixed, neutralized with baryta-water, and evaporated down to a small volume. This residue is rendered acid with dilute sulphuric acid, and finally is shaken up with small quantities of ether. On diluting the ether, benzoic acid is left behind in an almost pure condition. If not pure, it only contains traces of fat or ash constituents. For quantitative determination it is dried at 60° C. in the desiccator, weighed, the benzoic acid is sublimed, and the residue is again weighed. Sublimation is best effected on the water-bath, and is best carried on in such a way that the small basin containing the substance is covered with another basin of similar size, or with a watch-glass. The sublimate on the little basin lying on the top may be used for qualitative test, while the lower basin is heated uncovered for some time until all the volatile substances are expelled. The qualitative reaction for benzoic acid, which is the most striking, is its reaction with neutral iron chloride; the substance dissolved in water must, however, be treated with a few drops of sodium acetate.

Boiled milk may be detected from unboiled milk, in addition to the flavour test, by the ozone reaction, which unboiled milk gives but boiled milk does not. Unboiled milk colours guaiacum tincture blue, boiled milk does not. Potassium iodide starch-paper with oil of turpentine is quickly coloured blue by unboiled milk. Boiled milk does not exhibit this reaction, or at any rate no more quickly than the mixture itself becomes blue. The detection of starch in milk offers no difficulty. If starch has been added to cold milk, it settles on the milk being left standing, and can be easily collected in the bottom of the vessel. In order to detect the presence of boiled starch in milk, a large quantity of an iodine solution is necessary, since a considerable quantity of iodine is required to saturate the albuminoids before the iodine reaction is exhibited.



SHORTHORN COW—"MOLLY MILLICENT".

The property of Mr. Robert Thomson, Inglewood, Penrith. Winner of 1st Prizes at Royal Agricultural Society's Shows in 1887, 1888, and 1889.

CHAPTER III.

MILK IN ITS RELATION TO MICRO-ORGANISMS.—DAIRYING AND BACTERIOLOGY.

36. **The Bearing of Bacteriological Research on Dairying.**—Long before it was known that all fermentation and decomposition were caused by micro-organisms, the practice of dairying prescribed the greatest cleanliness in the treatment of milk and the great importance of always providing good pure air in all dairies; it showed the danger of exceeding a certain temperature, and recommended in cheese-making a careful regulation of the percentage of moisture in the cheese. The real reasons of these precautions were not known at that time, but experience taught that their observance was the best security against certain injuries to which dairy products were liable. We now know that uncleanliness leads to a rapid development of all micro-organisms, that musty stagnant air is heavily laden with spores of fungi and bacteria, that the activity of growth of these small organisms is influenced by the temperature, and that in general the damper and softer the fermenting mass is, the more rapidly does the development of fermentation take place. It is a fact that many bacteria which act as carriers of deadly infectious diseases, or as the creators of poisonously acting substances, can live in milk and render it poisonous. It has further been proved that certain bacteria cause the so-called spontaneous coagulation of milk, that others can exercise a disturbing influence on the creaming of milk and on the preparation of butter, and that other micro-organisms can cause the ripening of cheese in quite undesired ways. Just as, in dairy practice, it is desirable on the one hand to war against dangerous or unfavourable processes caused by bacteria, so on the other hand it is desirable to promote the action of certain kinds of fission fungi. For example, some are not only absolutely necessary for the process of cream souring, required in the production of fine butter, but also for the inception and development of the ripening processes to which the different kinds of cheeses owe their characteristic properties. The undisturbed and regular development of dairy manufactures depends upon the successful

regulation of a large number of fermentation processes. Since the technique of dairying is, as a matter of fact, dependent to a very large extent on ferments, which affect alike the distribution of milk for direct consumption or its utilization for dairy products, the necessity exists for everyone who takes an interest, either theoretically or practically, in the domain of dairying, to make himself familiar to a certain extent with bacteriology. It is especially necessary for the directors of agricultural experimental stations and laboratories to make themselves familiar with the science of bacteriology generally, and with the methods and details of the processes of investigation. The gradual abolition of the uncertainty surrounding dairy manufactures is the present important duty which lies before us, and its solution can only be effected by bacteriology. For this reason bacteriological research is of the highest importance to dairying, and it is this consideration which justifies our devoting a short section to its discussion.

37. **The Lower Fungi.**—Although microscopical organisms, especially bacteria, were discovered in the year 1675 by the Dutchman Leeuwenhoek, our knowledge of them was no further advanced. No idea could then be formed of their enormous distribution in the air, water, or soil, nor was it dreamt that they performed such an important rôle with regard to human life. Indeed, they were long regarded as harmless, and as performing no functions in terrestrial economy. Nevertheless it was observed that they occurred in large numbers in all fermenting and decomposing bodies. This phenomenon could be explained in two ways. The bacteria and the other low forms of fungoid life could be the exciting cause of fermentation and putrefaction, or, on the other hand, their presence might have nothing directly to do with these processes, and they might only be found in large numbers on such bodies because the fermenting and putrefying bodies provided suitable conditions for their development. In opposition to the vitalists, the supporters of the first-mentioned view, it was sought to trace fermentation and putrefaction to purely chemical and mechanical causes, especially to the oxygen in the atmosphere. At the end of the sixth decade of the present century a very interesting discussion took place between Justus von Liebig, who supported the chemico-mechanical theory of fermentation, and the vitalist, Pasteur. What had already been asserted by Spallanzani, Cagnard-Latour, Schwann, and others, with regard to the process of putrefaction, was soon

proved by Pasteur by direct and unbiassed observations to be true for the phenomena of fermentation, viz., that these processes were effected by minute organisms of the class of bacteria, fungi, and protozoa. When it was soon further proved that certain bacteria must be regarded as the undoubted causes of different infectious

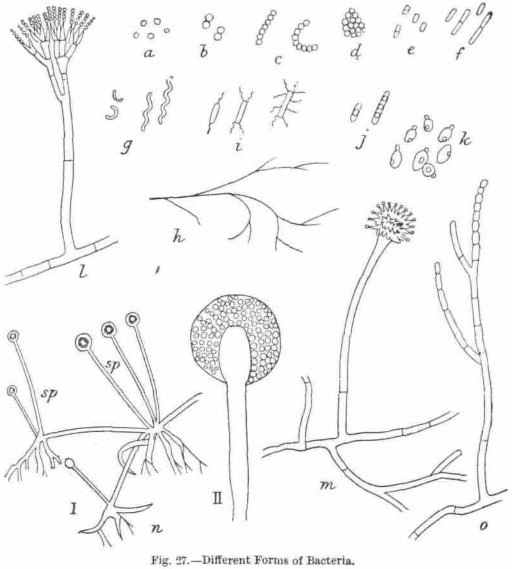


Fig. 27.—Different Forms of Bacteria.

a, Coccus; *b*, diplococcus; *c*, streptococcus; *d*, staphylococcus; *e*, bacterium; *f*, bacillus; *g*, spirillus; *h*, kladothrix; *i*, bacilli with ciliæ; *j*, bacilli with spores; *k*, yeast-cells; *l*, penicillium glaucum; *m*, aspergillus (mycelium with conidium); *n*, mucor stolonifer (I, mycelium bearing sporangia, *sp*; II, section through sporangium showing spores); *o*, oidium lactis. All greatly enlarged. After Freundenreich (from the report for 1893 of the Agricultural Experiment Station, University of Minnesota).

diseases, the full importance of the lower fungi in relation to health and life became recognized, and the study of their nature became of the highest interest. The micro-organisms, which are of the greatest importance in dairying, as is the case with the majority of all

those smallest of living growths known under this name, belong to the lower fungoid kind, which in their turn belong to the cryptogams. The lower fungi can be divided into fungi proper (moulds), budding fungi (yeasts), and fission fungi (bacteria). Their function in nature is to set up in the lifeless higher organic bodies a continuous process of disintegration and decomposition, and finally to mineralize them—that is, to convert them into water, carbonic acid, ammonia, nitric acid; in short, to change them into simple inorganic compounds, from which the entire higher plant world builds up its organic material.

According to the special phenomena which occur in such decomposition processes, according to the nature of the transition products formed, and according to the nature of the organisms which effect them, the process is called decomposition, putrefaction, or fermentation. *No decomposition can take place without the* presence of moulds or budding fungi. The characteristic putrefactive processes are essentially caused by fission fungi, and in the production of fermentation, budding fungi (beer and wine fermentation), as also acetic, lactic, butyric, and urea ferments, also take part. *In the development of their special action the different kinds* of the lower fungi exhibit different striking phenomena. Some yield colours, others cause phosphorescence, while others again produce liquids in which grow thick and slimy chemical ferments (enzymes), causing the production of odours and smells or the production of substances, which exercise on human and animal life an extremely poisonous action (ptomaines and toxalbumins). But the action of the lower fungi is not limited to lifeless organic bodies. There are numberless kinds which are able to take possession of living organisms, some of which not merely exist in living plants and animals or inside the human body, and as parasites feed upon their hosts in exceptional cases, but there are others which threaten them with degeneration and death.

The lower organisms possess interest for us in this connection in a threefold manner. For example, they are quite indispensable for the continuance of all living nature, inasmuch as they cause putrefaction and decomposition of dead organic matter, and render possible the development and the existence of the entire higher plant and animal world. Of the greatest utility are those by whose action the growth of certain kinds of our cultivated plants is assisted, and those which act in the preparation of certain foods as bread and

cheese, as well as the universally appreciated beverages wine and beer. Finally, they are not only deleterious, but also highly dangerous when they act as destroyers of the means of life, and as the exciting causes of many fatal diseases.

38. Distribution of the Lower Fungi.—The number and distribution of the spores of the lower fungi of all kinds are quite enormous in water, in the soil, and in the air. It is quite impossible, even with the exercise of the greatest care and cleanliness, to prevent cows'-milk, in the process of milking,—a process which takes place in the presence of the air,—from coming into contact with the hands of the milker and the milk vessels, and from thus absorbing a very large number of the spores of the lower fungi. Now, as milk, from the fact of its peculiar chemical composition, forms a specially nutritive medium, and offers most favourable conditions for the development of large numbers of budding and fission fungi, the result is that the spores are not destroyed, but, on the contrary, increased with very great rapidity. From a few spores in warm milk an incredible number of bacteria (from thousands to several millions per cubic centimetre) may be developed in the course of a few hours. It is obvious that milk which is strongly contaminated with luxuriant and growing fission fungi must have its ordinary dairying properties affected, and that its direct use may seriously threaten the health of the consumer. Among all the lower organisms which are of first importance in dairying are the bacteria, and for this reason they deserve our special attention.

39. The Forms and Life Conditions of Bacteria.—By bacteria, in the widest sense of the term, is understood all fission fungi. All bacteria or fission fungi consist of simple cells which are divided from one another, or are joined to one another in chains, bundles, heaps, or occasionally in firm glutinous masses. According to their form they are distinguished as follows:—The round, globular-shaped ones are known as *cocci*, *micrococci*, *macrococci*, and *diplococci*. The straight staff-shaped are called *bacilli*, and the spiral-shaped ones are known as *spirilli* and *spirochaeti*.

The conditions of development in which the cells exhibit active growth is known as the vegetative, and the growing cells are the vegetative cells. Growth always takes place in this way, that the cells divide into two halves (by fission), from each of which anew cell arises; hence the name, fission-fungi. In addition, moreover, many bacteria among the staff or spiral formed kind possess the

power of growth in another way, viz., by shedding seed-like bodies, the so-called spores, which, however, do not multiply as such. During this process, as a rule, there can be seen in the inside of the vessels themselves, brightly glittering bodies, chiefly pear-shaped, which subsequently develop into spores. While the vegetative cells are easily killed, the spores exhibit a high degree of resistance to unfavourable external conditions. The spores or the lasting cells, or lasting spores, as they are named, are cells which possess a thin but very compact membrane. Under favourable conditions they germinate and grow into a new and much larger vegetative form of fission fungi.

The life of bacteria is to a great extent dependent on temperature. With reference to this, every bacterium has a maximum and minimum, even an optimum degree of temperature at which it flourishes, and further, a point below or above which it dies. With reference to the low death point, it may be remarked that the influence of cold, especially repeated freezing and repeated thawing, according to late researches, is able to destroy many kinds of bacteria. The temperature above which death ensues lies, for the vegetative cells of the majority of bacteria, between 50° and 60° C., while their spores are able to withstand a much higher temperature. Most spores remain capable of germination even after being heated for a short time in liquids at 100° C., and many resist for a comparatively short time even a dry heat of 130° to 150° C.

These facts, which have been discovered by careful experiments under reliable conditions, possess the greatest practical importance. They teach that vegetative cells of almost all kinds of bacteria present in liquids are certain to be destroyed by heating for a comparatively long time (about two hours) at a temperature of 60° to 70° C., and that a liquid may be rendered perfectly sterile, *i.e.* free from resistant spores, if heated at 120° to 130° C., for a similar period.

In addition to temperature, the life of the lower organisms is still further influenced by the reaction and by the concentration, that is, the percentage of water of the nourishing liquid or the nutrient soil. Further, it is affected by the presence of bodies which exert a deleterious action on the cells, by the free access or otherwise of the oxygen of the atmosphere to the cells, and finally by electricity and by light. The ferments proper prefer a slightly acid reaction in their nutrient liquid or nutrient soil. The fission fungi, on the

other hand, prefer a slightly alkaline reaction. That dry organic matter is less liable to decay than damp is well known, and also that not only the products of the action of bacteria, but also many other stuffs, such as alkalies, in a state of strong concentration, carbolic acid, corrosive sublimate, chlorine, bromine, sulphurous acid, &c., exert a poisonous action on the bacteria. Many bacteria, especially those of the aerobic sort, are only able to live in the presence of a plentiful supply of free oxygen. Others, the anaerobic kind, on the contrary, as Pasteur first pointed out, require, for their development, the absence of free oxygen; while lastly there are others, the facultative anaerobics, which can exist under both conditions.

40. **Sterilization of Milk.**—It has been known since the year 1884 that sterilized milk, to which no sugar had been added, enclosed in hermetically-sealed tin vessels, has been known which could be kept perfectly well, and without losing its value, for use on board ship and for export to foreign countries. On the other hand, the great advantages of sterilized milk as an article of food, especially for the feeding of children, have not till recently been recognized. Its preparation has been first rendered possible by the work of Hueppe, and through the indefatigable, inventive, technical genius of Soxhlet.

After what has been stated in § 39, the question presents itself as the theoretically very simple one of destroying the low organisms in milk. Were the question only the destruction of vegetative cells, the continuous heating for 15 minutes at a temperature of 75° C. would be sufficient. This treatment is known as Pasteurizing. This is of exceptional importance for milk contaminated with pathogenic germs. The more important kinds of this type of germ, viz., those causing tuberculosis, typhus, and cholera, form, so far as present researches show, no lasting spores, and succumb therefore to very low temperatures. In the case of many spores of different kinds of saprophytic bacteria, however, which often occur in milk, and which impair to a very large extent its keeping properties, the only way to destroy these effectually when they are present is by means of a comparatively high temperature, either by simple or intermittent sterilization.

Milk is sterilized in the full sense of the term only when it has been rendered entirely free from germ-life by sufficient heating, that is to say, when all the lower forms of life which it contains, vegetative forms as well as lasting forms, are entirely killed, and any

enzymes formed by bacteria are destroyed. Perfect sterilization *can only be effected by submitting the milk to the action of* continuous heating for two hours at a temperature of 120° C., or for 30 minutes at a temperature of 130° C., or when it is submitted to intermittent heating at different high temperatures. The latter method of treatment, the so-called intermittent sterilization, avoids the heating of milk at temperatures over 100° C., and consists in heating the milk for two hours at a time at a temperature of from 70° to 75° C., then keeping it for several days at a temperature suitable for germ development, about 40° C., in order to permit the spores which are left behind to germinate and to form vegetative cells, then in order to destroy these to submit the milk for two hours at a time to a temperature of 70° to 75° C., then again to allow the milk to stand for several days at the same favourable temperature, viz., 40° C. These consecutive changes of temperature are repeated five times, one after the other, and at last the milk is brought to a temperature of 100° C.

In the above-mentioned treatment of milk, however, its properties undergo considerable changes. Among these changes is the conversion of its soluble lime salts into an insoluble condition. The result is that the milk no longer forms, when treated with rennet, a cohesive coagulation; while it coagulates under the action of acids in a fine, flocculent form. As a further result of this treatment, the fine condition of division of the milk-fat is somewhat altered. A large number of *the fatty globules of the milk come together, and after* a time there collects on the surface of the milk a cream which *resembles butter, and which can no longer be uniformly broken up.* Finally the milk assumes a dirty brown yellowish colour and a *strong taste of boiled milk. All these undesirable changes,* which affect the keeping properties of milk, take place in different cases more or less markedly, according to the method of sterilization, most markedly in the case where milk is heated for a longer period at 120° C., and least markedly in the case where it has been subjected to intermittent sterilization. For this reason the latter method of sterilization is to be preferred to all other methods of sterilization. Unfortunately, however, it is such an inconvenient method, and requires so much time, that it is not well suited for general application. No other course, therefore, is at present open than to dispense with perfect sterilization, and to be content with milk which has been temporarily sterilized.

Pathogenic—that is, disease-producing germs—as well as other dairy microbes of most common occurrence in fermenting milk can be destroyed by a steam heat of 68° to 75° C. for one hour's time, or for three-fourths of that time when the temperature is 100° C. This is so where the amount treated does not exceed one litre. For this reason it is comparatively easy to effect the complete sterilization without any alteration of its chemical composition, its colour, or the state of its fatty globules, provided the milk does not contain spores of a resistant nature. Unfortunately such pure milk rarely occurs in ordinary practice. Sterilization becomes very difficult in the common case of milk which has been contaminated, through dirty and careless handling, with very resistant spores, such as some bacteria belonging to the species of butyric acid, and hay and potato bacilli (for example, bacillus mesentericus, liodermus, butyricus, and subtilis).

From what has been already said, it will be seen that milk is sometimes easy and sometimes difficult to sterilize. Milk containing lasting forms of the above-described nature may keep at ordinary temperatures for about six months unchanged if previously heated for 45 minutes to the temperature of boiling water; yet at a temperature favourable to the development of bacteria it may coagulate, often with considerable development of gases, after only three or four days. Where coagulation ensues, this is never effected by the formation of acid, but always by enzymes formed by bacteria, which are of the nature of rennet. It is in the highest degree improbable, that lasting spores which have not been entirely killed in milk treated according to Soxhlet's method and then consumed should be able to germinate during the short, digestive period and exercise a deleterious action, yet it is not absolutely impossible. For this reason every effort should be made to effect the perfect sterilization of milk. Temporary sterilization, which is at present almost universally practised, would gradually become improved and brought nearer to perfect sterilization if it were only possible to obtain milk in ever-increasing quantities capable of being easily sterilized. For this purpose nothing further is wanted than cleanly handling of milk; and thus avoiding its contamination with such resistant spores of bacteria as above mentioned. How simple this demand seems to be when stated, and yet how extraordinarily difficult it is in practice to have proper attention paid to it!

Hueppe recommends that all milk destined for the use of

children should, before sterilization, be submitted to the action of the centrifugal separator, and the cream and the skim-milk separated in this way should be collected in the same vessel. He asserts that the most of the low organisms, and among them the most dangerous of the lasting kinds, remain behind in the mud residue, and that such treatment of milk renders it much more easy to sterilize. Whether treatment in the centrifugal machine does have this effect on milk is very doubtful.

Soxhlet suggests that cows should only be fed with scalded or steamed hay, in order in this way to prevent the contamination of the milk with the spores of the hay bacillus.

Although it may be admitted that perfect sterilization is not effected by the widely-known Soxhlet method of the treatment of milk, nevertheless it can be asserted that it, and the milk sterilization apparatus also designed for household purposes by Soxhlet, have proved themselves extremely useful. In the wide-spread application which the apparatus has met with it has proved itself eminently successful, inasmuch as it has undoubtedly contributed very materially to a diminution of the rate of mortality in children. Hueppe recognizes this, but regards the sterilization of milk in single households as only a makeshift, and he would regard it as a distinct improvement if the sterilization of milk could be accomplished in small bottles, either at the place where it is produced, that is, in the larger farms in the neighbourhood of towns, or in large municipal institutions. Only under such conditions would it become easy, he thinks, to gradually effect the sterilization of milk in large quantities.

In the first place it is in the interests of the management of the farm to pay the most careful attention to the cleanly treatment of milk, and in the second place, before sterilizing, the milk should be cleansed or purified in the centrifugal machine. Milk, according to Hueppe, is best sterilized on the spot where it is produced, by pouring it immediately after milking into half-litre bottles and exposing it in these for 45 minutes to a steam heat of 100° C.

In the Dresden dairy of Pfund the milk to be sterilized is first heated to 60° C., thereafter it is poured into the patent bottles, and these, after they have been closed, are heated in the steam apparatus for some time at 100° C. Milk intended for the nourishment of children is first treated in a centrifugal apparatus.

Milk which is temporarily sterilized, or, in the most favourable

cases, perfectly sterilized, has been recently called permanent milk. In its preparation different kinds of steaming apparatus are in use, among them that of Neuhaus, Gronwald, and Œhlmann is very popular. This apparatus renders it possible during heating to expel the air from the milk and the bottle, and after the heating has been finished to close the patent bottles by means of a lever in the apparatus itself before its cover is removed.

41. The Spontaneous Coagulation of Milk and the Souring of Cream.—The so-called spontaneous coagulation of milk takes place, as has been already explained in § 7, as soon as a certain quantity of lactic acid is formed by lactic fermentation. The amount of lactic acid produced depends on the original condition of the milk, and the quantity of ferments present. It is dependent also on the temperature. It has been already noticed that there are a *comparatively large number of forms of genuine lactic bacteria* very similar to one another both in their form and properties, which together are able to effect the formation of lactic acid and the spontaneous coagulation of milk. Some, and this especially applies to the *bacillus acidi lactis* of Hueppe, split up the molecule of milk-sugar with comparative ease into four molecules of lactic acid, and produce at the same time an extremely slight evolution of carbonic acid. Others produce small quantities of secondary bye-products, especially alcohol, and others, again, develop in addition very minute quantities of odorous bodies, regarding which very little else is known. Various indications, as has been pointed out, show that in the spontaneous coagulation of milk the caseous matter does not seem to remain unchanged, as is the case in the artificial precipitation by addition of acids, but undergoes slight changes.

The most important practical application of lactic fermentation is seen in the souring of cream for the manufacture of butter, an operation which takes place every day in dairies. Bacteriology has already annexed this operation as a suitable field for investigation. Ever since it has been shown to be probable that all kinds of lactic bacilli are not equally well adapted to act as ferments in effecting this change, the attempt has been made to isolate and to cultivate in pure cultures the particular varieties which are believed to produce the best butter with the finest aroma. In order that this may be accomplished, it is necessary to describe exactly how a fresh and pure daily supply of the souring liquid, or, as it is called, the acid generator, is obtained. It has been recommended to infect with a

pure culture of the bacilli in question a sufficient quantity of fresh skim-milk which has been once, or oftener, heated to 70° C., and then cooled to the temperature required for souring, viz., about 16° C., then to allow it to become sour, and when this has been accomplished to use it as a souring agent. The cream to be soured may be previously Pasteurized, and, it is hardly necessary to mention, should be carefully protected from contamination. The daily employment of pure cultures of lactic ferment for cream souring can scarcely be expected to come soon into regular practice, and no wide-spread demand appears to exist for them as yet. On the other hand, in course of time such pure cultures will probably come to be used more and more, and the more so as it becomes better understood that undesirable properties in butter have probably their origin in the improper souring of the cream.

42. **Different Kinds of so-called Milk Diseases (Milch-fehler).**—Occasionally it happens that milk or cream coagulates without any previous lactic fermentation. For example, we need only cite the coagulation of boiled milk, in which the reaction is neutral, and the cheesy appearance assumed by cream, in which the precipitation of caseous matter is certainly not effected by lactic acid. The coagulation of milk of neutral reaction, spoken of by some as sweet-milk coagulation, is effected by means of different kinds of bacteria, which Duclaux has grouped under the name *tyrothrix*. These fission fungi, which for the most part belong to the group of the so-called potato bacilli, give rise to enzymes of the nature of rennet, which precipitate the caseous matter in milk possessing a neutral or even a slightly alkaline reaction, and which in time dissolve more or less perfectly the coagulated mass. If milk which has been repeatedly boiled does gradually coagulate, and this while showing an almost entirely neutral reaction, such a condition points to the presence of bacteria of this class, whose lasting spores have been enabled to withstand the boiling temperature which has destroyed the lactic bacilli.

Many disturbances of milk, which occur in creaming and in the preparation of butter, and the causes of which were formerly sought for in disease of the cows, in the influence of weather, and especially in the physiological action of certain foods, that is, in quite erroneous causes, have now, through bacteriological investigation, been certainly traced to fission fungi.

Where premature or unusually rapid coagulation occurs, there

can be no doubt that the milk contains an extraordinary quantity of luxuriantly-growing lactic bacilli. If milk *during creaming* becomes fermented, or during the manufacture of cheese yields puffy cheese, all these indications point assuredly to the presence of a large quantity of a certain kind of fission fungi, and possibly also of budding fungi.

The mystery which formerly surrounded certain changes in milk, by which it was rendered slimy or ropy, has to a certain extent been cleared up. It has now been proved that the viscous consistency of such milk has been caused either through a slimy body produced by the decomposition of the milk-sugar, or is due to the fact that the milk contains masses of bacteria, chiefly cocci, in the form of zoogloa bacteria, the cell membrane of which has experienced a peculiar change, associated with a large amount of swelling. In the first case, certain micrococci produce from the milk-sugar a slimy substance, about which very little is known, and also small amounts of carbonic acid, and occasionally also mannite. In the second case it would appear that no decomposition of the organic constituents of the milk seems to take place by the action of the luxuriantly-growing slimy masses of bacteria. Different kinds of bacteria impart to milk an unpleasant, bitter, slightly rancid, and disagreeable flavour, by either causing the production of butyric acid, and perhaps also formic acid, or by separating peculiar bitter extractive substances.

Formerly it often occurred that on the surface of milk set for cream, coloured patches, red, yellow, or especially blue, were after a time developed; or that the entire mass of the milk assumed a similar unusual colour. These phenomena are also caused by the action of fission fungi, viz. colour-producing bacteria. At present only one kind of bacteria is known which can colour milk blue and one which can colour it yellow, viz. the *bacillus cyanogenus* and the *bacillus synxanthus*, which are known in several varieties, and which live in symbiosis, that is, live together with other kinds of fission fungi. On the other hand, there are many kinds of bacteria, chiefly belonging to the group of micrococci, which impart a red colour to the surface of milk or cream. The most of these bacteria do not exert a decomposing action on the organic constituents of milk. The widely distributed *micrococcus prodigiosus*, which under certain conditions produces blood-red patches on the surface of milk, on the contrary effects, in the first instance, a decomposition

of the caseous matter, and subsequently redissolves a portion of the coagulated mass, leaving in addition in the milk the unpleasant flavour of herring-pickle (trimethylamine). *Bacteria lactis erythrogenes* coagulates the milk and imparts to it, if light be excluded, a uniform blood-red colour; and a kind of *sarcina* produces a brown-red colour in the milk.

In feeding with milk which is infected with colour-producing bacteria, no deleterious action has yet been observed to be produced. Such bacteria seem, therefore, not to exert a deleterious action on the animal body. It is obvious that all the influences due to fission fungi, which exert a disturbing effect on dairy practice, can be imparted by means of the organisms and the spores from one mass of milk to another, that is to say, they are infectious. For this reason, the only way of curing them where they exist is by the destruction of the respective fission fungi.

It is often very difficult to remove effectively the disease germs present in milk, since the conditions of breeding favourable to the organisms in the milk are not known, and also because almost nothing is known of the development of the individual fission fungi.

43. Micro-organisms in Cheese.—That the ripening of cheese is connected with and influenced by micro-organisms, and is successful or the reverse, according to the nature of the organisms that are present in predominating amount, is beyond doubt. Since it has been proved that the organisms which are present in the cheese from the first are largely developed during the ripening period, and since the ripening will not take place when certain substances which are fatal to germ-life are introduced, although these may not have any influence on the albuminoids of milk, or when fresh cheese is protected from the action of air, it follows that it is the low micro-organisms which effect the ripening in all cheese. Since all the different kinds of micro-organisms produce definite effects, it further follows that each individual cheese requires for its ripening a special kind of micro-organism. As our knowledge of the use of different kinds of micro-organisms—for producing the many different kinds of cheeses, and without which the specially desired effects of the ripening are not obtainable—increases, the great uncertainty which at present prevails in the manufacture of cheese will gradually vanish. But the application of a knowledge of the specific action of the various micro-organisms to the manufacture of cheeses is not easy, and we can scarcely hope to see it soon successfully effected. The subject is

a very complicated one, from the fact that the proper ripening of cheese is the result of the co-operation of different kinds of micro-organisms; a symbiosis or metabiosis in which certain kinds of bacteria partly favour and partly retard the simultaneous development in the same medium of other kinds of bacteria, or in which one kind first prepares the way for and renders possible, to a certain extent, the action of another kind.

As has been already pointed out, there are fission fungi which produce peculiar ferments, which exercise a solvent effect on the coagulated caseous matter. Probably no kind of cheese can do without the action of these fungi for its ripening, by means of which the original white and friable or fragile cheese is converted into a yellow-coloured, soft, pasty mass. For all cheeses which are soft, and which have a tendency to become liquid, the fission fungi are without doubt of first importance. In the ripening of some cheeses, for example Roquefort, Gorgonzola, Brie, Stilton, &c., certain fungoid organisms cannot be dispensed with, since they, as has been explained, check the action of the lactic bacteria, and gradually diminish the acid reaction of the mass to such an extent that the bacteria which produce the decomposition of the albumin are permitted to develop.

Long before bacteriological investigation had thrown light on the subject, practice had instinctively sought the help of fungoid organisms for producing certain peculiar characteristics of certain cheeses. In the preparation of Roquefort cheese, for example, the cheese-makers were in the habit of mixing the fresh cheese with fungoid organisms, and in the preparation of other kinds of cheese they had endeavoured so to arrange the treatment of the cheese that the colonizing and development of fungoid growths should take place as quickly as possible on its surface and in its inside. On the other hand, in the ripening of other kinds of cheese, the action of the albuminoid destroying bacteria has been held in check by the lactic bacteria, since the cheese would otherwise be liable to premature decay.

In Holland, in the preparation of the Edam cheese, practice has likewise preceded theory. In that country, when milk which has to be used for churning is treated with sour milk, there is added to it, if not a pure cultivation, yet one in which the growth of colonies of such bacteria (*cocci*) predominates, as experience has shown these cannot be dispensed with in the ripening period.

In all ripened cheeses the presence of butyric acid can be

detected, sometimes in larger and sometimes in smaller quantities. It is without doubt formed directly from milk-sugar by butyric acid fermentation. It is indirectly formed for the most part from other substances, which vary according to the kind of cheese and the kind of organism active in the ripening process. Such substances are hydrated milk-sugar, salts of lactic acid, albuminous bodies of milk, milk-fat, or glycerine, formed in the saponification of milk-fat.

The organisms which interfere with the processes of ripening, and which influence the products of ripening, have also been investigated. A very objectionable, and, at the same time, very commonly occurring disturbance is the inflation of cheese. Many kinds of lower organisms are already known which, under certain conditions, are able to excite a kind of fermentation in ripening cheeses which is associated with a strong evolution of gaseous bodies. Such are the various kinds of *micrococci*, the *saccharomyces lactis*, the yeast discovered by Duclaux, and other kinds of yeast, *tyrothrix urocephalum*, the *masticis cocci*, *bacterium lactis aërogenes*, *bacterium coli commune*, and others. In cheeses, on the surface or inside of which red patches are developed, the presence of moulds, which in the condition of sporulating produce a brick-red colour, have been detected, as well as several kinds of micrococci, and also very probably a kind of torula. A peculiar kind of disease cheese is subject to, in which it becomes blue, has been probably traced to a kind of bacteria which only flourishes in the absence of air (de Vries); while the production on parts of the surface of cheese of black patches which easily become sticky have been traced also to several different kinds of fungoid growth.

44. Characteristics of Milk which Owe their Origin to Micro-organisms.—That milk which has been standing for some time owes its peculiar properties to bacteria, is known, although little is known as yet regarding their nature. In a similar way the organic ferments which yield the purest and best koumiss still await investigation.

Kephir, a slightly effervescing spirituous beverage, prepared from milk, contains the common chief constituents of milk in a slightly altered condition, in addition to minute quantities of carbonic acid, lactic acid, alcohol, and peptones. It also contains caseous matter in a firm but very finely divided condition, well known as kephir grains. In this beverage, several different kinds of yeasts and bacteria have been identified. The yeasts differ from

the common beer yeasts, and are not able alone to cause the fermentation of milk-sugar. This can only take place after the milk-sugar has been dehydrated by the bacteria present in the kephir grains. These bacteria act in different ways, some being able to induce lactic fermentation, others to dehydrate the milk-sugar in presence of certain yeasts, and others to partly peptonize the caseous matter.

45. **Destruction of Micro-organisms.**—In conclusion we may say a word or two on the methods of destroying the microscopic enemies of dairying, and the methods of effecting complete cleansing of milk-vessels and the disinfecting of dairy rooms. For cleansing of vessels of all kinds, different materials may be used according to their nature, such as steaming under pressure, treating with hot strong alkali solutions, preferably boiling soda solutions, or solutions in which burnt lime has been dissolved. The disinfection of rooms or spaces can be effected by covering the walls and ceilings with freshly prepared milk of lime, or with a solution consisting of calcium sulphate, and sprinkling the floor with an alkaline solution. Bad flooring should be thoroughly repaired or entirely renewed. In order to clean the hands one should wash them over with black soap or a solution of creasote. Poisonous disinfectants, such as mercuric chloride (corrosive sublimate) ought not to be used in dairying.

46. **The Practical Application of Bacteriology.**—From the above statements it may be safely asserted that dairying has already much for which to thank bacteriological investigation. Bacteriology has drawn our attention to the existence of a large number of well ascertained and valuable facts that have new and highly important and practical bearings on dairy practice. It has shown that dairying must reckon in practice with small, and, so far as the naked eye is concerned, invisible friends and foes. It has further taught the desirability of sterilizing and Pasteurizing milk and its liquid by-products, and in this way has conferred great benefits—benefits which are not half sufficiently recognized—by showing the importance of such treatment, not merely from the physiological and sanitary point of view, but also in the technical interests of dairy manufactures. It has further discovered the true causes of many troublesome disturbances or diseases of milk, and has already pointed the way, in at least a large degree, to their cure. Finally, it has opened a prospect of the possibility of successfully combating tuberculosis in cattle.

CHAPTER IV.

THE MANUFACTURE OF BUTTER.

47. The Different Methods in which Butter is Made.—Butter is the most important product of milk. As usually manufactured, fresh butter contains about 83 to 84 per cent of milk-fat, 14 to 15 per cent of water, and 1·2 to 2·2 per cent of the other constituents of milk. The percentage of the single chief constituents of the non-fatty total solids of butter, if not exactly, is approximately the same as in milk. Hitherto it has not been possible to obtain, in the form of butter, all the fat which any quantity of milk contains.

In the preparation of butter the object aimed at is to solidify the largest possible number of fatty globules in the milk, and then to incorporate them. This has been hitherto, and still is effected, by churning, which consists in shaking violently the fatty globules, and by this violent motion bringing them into intimate contact with one another. Although butter can be obtained by direct churning of the milk, an easier and preferable way is to collect the larger portion of the fatty globules by allowing the milk to be divided into two layers, the top layer, which contains as much fat as possible, constituting the cream, and the lower layer, the skim milk, which may be five to six times deeper than the top layer, and contains the least possible amount of fat. The skim milk is separated and the cream is churned. This separation was effected up to the year 1877 by setting the milk in suitable vessels so as to permit it to collect. It was left for from 12 to 48 hours, and even longer, until the greater part of the fatty globules, owing to their light specific gravity, collected on the top, and formed a layer easily recognizable by the eye. In this way the milk was divided by a sharp line into two layers, the skim milk and the cream. Since the year 1877 centrifugal force has been employed for the separation of cream from milk, and the use of this method has extended every year since. There are thus two methods of obtaining cream, the old and the new.

It is perhaps not superfluous to notice that cream and butter are not

the same as milk-fat or butter-fat. It is not correct to speak of the percentage of cream or butter in milk, since cream and butter are not milk constituents, but milk products.

48. The Old Method of Cream-separation — Cream-raising. — According to the formula given in § 6, it is easy to calculate the acceleration which drives the fatty globules of the milk to the surface (not taking into account any opposing forces) to be about 120 centimetres, or the eighth part of the acceleration of free-falling bodies. The fatty globules in milk would, therefore, in the first second of their movement, were it not for the friction due to their movement, traverse 60 centimetres. Consequently, in layers of milk not deeper than 60 centimetres the fat globules should be collected on the surface in about a second's time. That this does not actually take place, in point of fact, in cream-raising, is due to the friction, which is exceedingly great in the case of the extremely minute fatty globules. The ease with which single fatty globules *overcome resistance of different kinds is dependent solely on their size.* The large globules, of which some weigh 244 times more than the smallest, overcome this resistance very easily, for they come to the top in a deep milk layer very quickly, some of them certainly in less than a minute. This is the case in warm fresh milk. The smallest, on the other hand, are unable to overcome this resistance and no longer exhibit independent motion, but follow the milk-serum wherever it carries them. The rate at which the *globules tend to come to the surface depends directly on their size.* Were all the remaining constituents of milk in a state of solution, the rising of the cream would take place with comparative ease, since the fatty globules would only have to overcome the internal friction and resistance which their motion entailed, and the resistance offered by the currents caused by their movements in the serum. But further opposition is experienced by them through the fact that the caseous matter, and possibly also some of the mineral salts of the milk, are not in a state of solution, but are in a precipitated condition. We call the state of precipitation perfect when it offers comparatively little resistance to the motion of the fatty globules, and imperfect when it offers, on the other hand, a large amount. Generally speaking, it may be said that the state of precipitation of the caseous matter is most perfect in fresh milk, and becomes gradually less so in the course of about three

hours, even although the surrounding conditions are exactly the same. It is further known that, with an increasing percentage of lactic acid in milk up to the point of spontaneous coagulation, the precipitation of the caseous matter becomes more and more imperfect. It is also known that it is not the same in samples of milk of different origin, and that it is sometimes more perfect and sometimes less perfect, according to the exact composition of the mineral salts of the milk. The fatty globules, in their motion, have to push aside or push through the coagulated masses of serum. It follows from the nature of the molecular forces coming into play in this connection, that the resistance offered by the different causes mentioned diminishes with the rise of temperature and increases with the lowering of temperature, and also that the condition of the precipitation of the caseous matter is more perfect the higher the temperature. The resistance above referred to is only to be reckoned with in the case when the milk-serum is at perfect rest during creaming, or when, at any rate, no vertical current movements exist in the milk. It is difficult, however, to prevent currents arising in creaming operations, due to cooling. The colder portion of the milk, being of greater specific gravity, sinks to the bottom, and the warmer portion, being lighter, rises to the top. In this way the collection of fatty globules on the surface is disturbed and impeded. The descending currents carry away more fat with them from the cream layer than the ascending currents bring back to the surface. It is only after the entire mass of the milk assumes the same temperature as the surrounding air, and when no further changes owing to temperature are induced, that the fatty globules can follow without disturbance their tendency to collect on the surface. For creaming the following conditions are necessary:—

(1) Milk should be set immediately after milking, since the conditions of coagulation of the caseous matter are then most perfect.

(2) Cream-raising ought to be carried on at the highest possible temperature, in order to avoid, as much as possible, the resistance the fatty globules meet with in coming to the top.

(3) The milk of large and well-fed cows should preferably be used, since it is very probable that such milk will possess the usual properties of milk, and especially will undergo a proper coagulation of the caseous matter.

(4) The progress of lactic fermentation, which unfavourably influences the coagulation of the caseous matter, should be retarded

by all available means, such as cooling the milk to a low temperature, the observance of *the greatest cleanliness in handling the milk*, as well as in the rooms where cream-raising is carried out, and by taking care that only pure dry air should be provided in these rooms, and that they should be properly ventilated.

(5) The currents induced in milk by cooling, especially those moving in a perpendicular direction, should be prevented, or should be reduced to the shortest possible duration.

The extent to which these requirements are carried out will depend on the amount of fat obtained in a given time from the layer of cream, and the success of the cream-raising. The requirements which demand that the milk, on the one hand, should be kept as warm as possible in order to minimize the amount of resistance, and those, on the other hand, which demand that the milk should be kept as cool as possible in order to lessen lactic fermentation, are contradictory to one another. Since, however, the second requirement is undoubtedly of greater importance than the first, there is no option but to fix the temperature of cream-raising so low that the milk will keep sweet—*i.e.* that on boiling it will not coagulate—at least thirty-six hours. Practice has long demonstrated that this is the case with a temperature of 12°, or at the most 15° C., provided *all* precautions as to cleanliness have been observed. This is, therefore, the temperature to be recommended.

Formerly there was a comparatively large number of different methods of cream-raising in use, each one of which possessed special advantages of its own. The most widely used and the most perfectly developed was that known as the Holstein method, which originated in Schleswig-Holstein. Now, with hardly an exception, all these methods have become antiquated, and are no longer used in the larger new dairies. All the older methods of cream-raising are at one in requiring that the greatest cleanliness should be observed, and that the milk should be set immediately after milking. They all, including the Swartz and Devonshire methods, prescribe also a certain temperature to which the milk, as it comes from the cow, has to be cooled, and require that milk should be maintained in the further stages of the process at the cream-raising temperature. In other respects they show considerable differences in respect of the temperature to which the milk is raised, the greater or less speed with which the warm milk is cooled to the cream-raising temperature, and the method in which the cooled milk is maintained at the

equable creaming temperature. The time occupied in cream-raising, the form and the material of the vessels used in the cream-raising, the depth of the milk-layer in the vessel, the rules laid down with regard to the condition of the room in which the cream-raising is carried on, and the method in which the cream is removed, also vary according to the method adopted. In all methods of cream-raising the milk possesses an equable temperature during only a portion of the entire cream-raising period. During the first hours, that is, until it has been gradually cooled down to the prescribed temperature, milk creams at a comparatively higher temperature, since the resistance offered to the fatty globules is comparatively less. The creaming temperature is, therefore, the lowest temperature to which milk is cooled down, and at which milk is sought to be kept. It varies in the different methods of cream-raising here considered between 9° and 24° C.

The more particular conditions under which the coagulation of the caseous matter is unfavourable for creaming have been already dealt with in § 21, when discussing milk which creams with difficulty.

It is always a disadvantage if the highly favourable conditions which exist during the first hours after milking are not utilized for creaming. Experience has taught that milk which has been kept for some time after milking and has been cooled, or again disturbed, or left temporarily quiet, and again disturbed, always yields a less satisfactory quantity of cream than milk derived from the same source which is at once set after milking.

That the slightest disturbance of milk during cream-raising exercises an appreciable influence on the collection of fat in the cream can be easily understood when we remember the comparatively small quantity of fat globules distributed throughout the milk. For this reason, it is only natural that under like conditions, the less milk is disturbed, the greater the quantity of fat obtained in the cream. The collection of fat on the surface of milk at first takes place very rapidly, and diminishes the longer it proceeds. Even when the cream-layer which has been formed is no longer increased, its percentage of fat nevertheless continues to increase steadily as long as the creaming continues. For this reason, in every method of cream-raising, there is a certain period of time, the so-called cream-raising time, at the conclusion of which the cream is removed, since the increase in the percentage of fat in the cream after this

takes place so slowly that it is no longer worth while to let the milk stand.

The sooner the vertical currents, due to the cooling of the milk, cease, and the fatty globules are enabled to exercise their tendency to rise to the surface without hindrance, the more successfully will the process of cream-raising be carried on. If metal vessels are used in cream-raising, and care is taken that the milk is cooled by the application of cold to the sides and bottom of the vessel, vertical currents may be altogether avoided, and creaming may be permitted to take place under the most favourable possible circumstances.

There are no substances which, when added to milk, hasten the process of creaming, and if chemicals are added to milk for the *purpose of retarding premature coagulation, such treatment is liable* to be regarded in the light of adulteration.

In the case of comparatively high equable temperatures—from 10° C. upwards—the collection of cream takes place by the formation of a comparatively small layer of cream at first, which is gradually increased. The fatty globules collect in the cream-layer according to their size, the largest globules coming to the surface first, and the smaller ones less quickly. *In the case of lower equable temperatures*—10° C. and downwards—the milk-serum is comparatively viscous, and in consequence the fatty globules experience in their movement greater internal friction. As long as the fatty globules in cream-raising are not brought into close contact with one another, they find their way to the surface undisturbed, more or less quickly, without reference to their size. In a short time, however, it is impossible for the larger globules to overtake unhindered the smaller ones. Blocks occur in the ever-increasing swarm of upward-striving globules, and there is seen, as a rule, after a longer time, a comparatively thick layer of cream, which, owing to the fact that the fatty globules are slowly pressing up on one another, gradually becomes more concentrated.

The lower the temperature at the end of the creaming period, the greater is the expansion, weight, and amount of water in the cream-layer, and the smaller is the percentage of its fat, after the lapse of a certain time and in the case of a fixed degree of temperature. On the other hand, if milk of similar composition and under similar conditions be set for creaming, the higher the creaming temperature the less will be the cream, and that cream will contain less water and correspondingly more fat, besides being more viscous.

The higher and narrower the vessels used for cream-raising are, the deeper and less compact will be the layer of cream, and the less will be the percentage, that is, the absolute percentage of the fat of the cream under otherwise like conditions.

As will be seen, the thickness of the layer of cream depends on certain particular conditions under which creaming takes place to a greater extent than on the percentage of fat in the milk. It may happen, as a general rule, that milk richer in fat yields under exactly similar treatment a deeper layer of cream than milk poorer in fat; but this is not always the case, and if milk richer in fat throws up more cream, the depth of the cream-layer of milk from different sources is seldom exactly proportional to the percentage of fat it contains. Conclusions as to the percentage of fat in milk, derived from the depth of the cream-layer, or the amount of fat which creaming yields, are for this reason highly unreliable.

49. The Older Methods of Cream-raising.—Under the older methods of cream-raising, the best known are the Holstein, Gussander, Swartz, and Reimer methods. Other methods of cream-raising, which have scarcely been attempted in Germany at all, but which have been adopted in other countries, and to which references are often met with in the literature of the subject, are the Dutch, Devonshire, Orange County, Cooley, and the American clotted-cream method. Among these different methods, the only one which is in use at the present day in Germany in the larger dairies is the Swartz method, and a slight variation of this method, viz. the cold water method—where the conditions necessary for its utilization are present. The remaining methods of cream-raising which have not altogether died out, viz. the Holstein and the Satten (similar to the Holstein) methods, are no longer suited for present requirements and may well be described as antiquated. The Swartz method will be described in the succeeding paragraph.

The methods of creaming which are now obsolete may be enumerated as follows:—Holstein (and the Destinon, which is a modification of the Holstein method), the Gussander, the Reimer, the Dutch, the Orange County, the American method of mass-creaming, the Cooley, the Devonshire, the Pommritz, the Natron, the Tremser, the Becker, the Hacks, the Kellog, the Electrical, the Speedwell, and the Kalma.

The separation of the cream from the skim-milk is effected either by skimming the milk, or by allowing the skim-milk to flow carefully

away from under the cream. For many reasons the former method is to be preferred.

50. **The Swartz Method of Cream-raising.**—This method, devised *in 1863 by Gustav Swartz, of Hofgaarden, near Wadstena, in Sweden,* requires an area of creaming space per cow of as much as half a square metre, so that there is an excessive demand for creaming space. It is directed in this method that the milk be poured into special vessels, known as the Swartz milk-pans. These are long four-cornered tin vessels, with rounded edges 50 centimetres high, and of a capacity of 36 to 50 litres. The milk is poured in to a depth of 40 centimetres. The milk-pans when thus filled are placed in a long square receptacle, which is made of sufficient size to hold *at least six or at most ten cans.* They are then packed with ice and left standing from 12 to at longest 24 hours. During this time the milk is cooled down to within a few degrees of freezing point. Swartz recommended that the sweet cream should be immediately churned, and he thus gave an impetus in Sweden and Denmark to the first attempt to introduce sweet-cream churning on a large scale, and to place upon the world's market sweet-cream butter (fresh butter) as a keeping butter.

As soon as the warm milk is placed in ice all vertical currents *cease, since cooling takes place chiefly on the bottom and sides of the* milk-cans, and not from above. Only currents flowing in almost a horizontal direction, from the outside to the inside and *vicê versâ,* take place, which, so long as the milk-can is not broader than say 16 to 20 centimetres, do not to any extent hinder the fatty globules in their ascent to the surface. According to the author's observations, warm milk when placed in ice in Swartz milk-pails requires from three to four hours to cool down to about 10°C. It stands, therefore, for several hours at temperatures at which the opposition offered to the movement of the fatty globules is comparatively slight. This, and the complete absence of vertical currents, are the causes why *more fatty globules rise into the cream-layer in the* Swartz method, during the first hours of cream-raising, than in any other older methods of cream-raising. Even after 12 hours the yield of cream in the Swartz method is almost always greater than in the Holstein method under similar conditions. As soon as the temperature of the milk falls below 10° C., the opposition in the milk-serum rapidly increases, and impedes the motion of the fatty globules to the surface more and more with the lapse of time. After 24 hours the

yield of cream in the Swartz method is almost always less favourable than in the Holstein method, and still more so after 36 hours. In general, it may be said that it is not possible with the Swartz method to get in the course of the year so much fat as is possible with other methods, as for example, with the Holstein or the Gussander methods. The Swartz method is only suitable for dairying in which the production of perfectly sweet cream and skim-milk is the object aimed at, and in which the highest possible yield of butter is not aimed at, but where it is desired rather to produce skim-milk of not too poor a quality.

Such conditions occur in all dairies where the proprietors are in a position to utilize the perfectly sweet and moderately skimmed skim-milk for cheese-making, or for the rearing of calves, so that a greater return may be obtained for the gallon of milk under these circumstances than if the largest possible yield of butter were obtained at the expense of the condition of the skim-milk. The Swartz method is therefore of great value in many dairies, and will continue to possess that value wherever skim-milk is made to any extent into cheese. It has been introduced with peculiar disadvantage into dairies in which the only object is a high yield of butter, and in which no cheese is made.

In the Swartz or ice method, for the cooling of every kilo. ($2\frac{1}{4}$ lbs.) of milk, on an average ·85 kilo. (about 2 lbs.) of ice is used. For North Germany, Sweden, and Denmark the price of a kilo. of ice, taking into account the outlay, the depreciation, and the interest on the ice-house, is about ·32 pfennig. The cooling costs about ·27 pfennig. This is equal to 6 marks per cow (yielding 2000 kilos. of milk in the year). The expense of an ice-house, built according to the Danish method, and suitable for treating the milk of 200 cows, amounts to about 6000 marks, and to about 4500 marks for an ordinary ice-cellar, capable of treating the milk of about 100 cows.

51. The Cold Water Method.—A variation of the ice method is the cold water method,[1] which in its correct form only differs from the former by the fact that an abundant supply of cold running water is used instead of ice in cooling the milk, and that the milk is left to cream for 36 hours or longer. In this method, the yield of fat from milk is, on an average, greater than is the case in the ice method. It is admirably suited for hilly districts in which the supply of cold

[1] An application of this method, under the name of the Jersey Creamer, has attained considerable popularity in England.—*Editors English Edition.*

flowing water is abundant, but the method is not suited for districts in which this is not the case. An attempt was formerly made in North Germany to introduce a method of cold water cooling, which consisted of cooling with water that had been pumped through ice, or with spring water that had been allowed to flow through a suitable ice-house or ice-metre. This attempt, however, has met with little success.

52. **The Collection and Storage of Ice.**—As the opinion is becoming more prevalent every day that ice is indispensable for all the best-equipped dairies, it may be not out of place to add to the description of the ice method given in § 50 a few words on the *most suitable method for storing ice.*

Very few dairies are in the position of being able to purchase at economical prices the supply of ice they require from day to day. Most of them are forced to lay in for themselves larger quantities of ice, and to keep these for a long time in blocks or in ice-houses. For this purpose, the great difficulty is to minimize, as far as possible, the loss which is apt to take place through melting during warm summer weather. The loss is partly due to the contact of the vessels *containing the ice with air, or some solid body which has a* temperature above the melting point of ice, but to a far greater extent to the fact that during the warm weather a stream of warm air is constantly passing night and day over the surface of the ice-layers. All spaces in the ice-layer filled with air yield up their heat to the ice, and melt a certain quantity of it. The confined air finally assumes the temperature of melting ice, and becomes of heavier specific gravity than the warm air outside, and tends to sink, *owing to its weight, through all the fine pores and crevices surrounding* the lower portions of the ice-heap, outwards, and is replaced by warm layers of air coming in from above and from the sides.

If ice be preserved in layers, as is commonly done, or in wooden ice-cellars or in wooden ice-houses, it should be surrounded with substances which are bad conductors of heat, and which keep the air from occupying the interstices and pores, besides offering a barrier to the movement of the stream of air. In this way the loss through melting may be largely diminished. If it were possible to prevent absolutely the movement of air over the blocks of ice, the loss would be reduced to a very slight extent, provided the surface remained dry.

For this reason it is necessary to take precautions to provide a good covering material for the roof. Sawdust, turf, and ashes are

well suited for this purpose. It is further important to keep the covering material always dry, since it loses its properties as a bad conductor of heat when it becomes wet. It may, indeed, generate a certain quantity of heat through becoming fermented. It is further necessary to provide every space which contains a heap of ice with a chimney, so that evaporation of the water from any ice that has melted may be allowed to take place, and the covering material thus remain dry. Every ice-store should also be built in such a way that the melted water may quickly run away.

Ice should preferably be kept in houses with solid walls which effectually keep out the air, and which are sunk considerably underground. They should only possess one entrance towards the top of the building, and it should have double doors and a drain for allowing the melted water to run off. A covering is not only unnecessary, but in the case of its being of an organic nature, it is positively a disadvantage. In such houses the passage of air currents over the layers is very much impeded.

The less the intervening spaces between the layers of ice are, the less will be the quantity of air coming into contact with the layers. For this reason it is desirable that ice should be kept in regular rectangular four-cornered pieces, which may rest close together, and which should be cut, not by breaking, but by sawing. It is advisable to fill up the spaces between the separate pieces with sawdust. Small pounded ice is not suitable for this purpose, nor is it effected by pouring water in cold weather over the layers of ice. The fewer the pores in the ice the better it keeps. On this account firm good ice only should be used, not such as has been subjected for some time to the action of a thaw. In order to obtain ice which is hard and smooth on all sides, special blocks should have the snow cleaned off them after every snowfall. Ice for use should never be taken from the lower portion of the layer. If this be done, every time the ice-stack is opened the cold heavy air which it contains is expelled, and is replaced by warm air, which exerts a deleterious action on the keeping of ice. If, on the other hand, the ice-stack is opened from above, the cold heavy air remains in the stack, and the warmer lighter air from outside cannot penetrate down into it. Ice should be laid in during frost, and snow during a thaw. A snow-stack collected during a thaw, and well compressed, lasts under similar conditions even better than an ice-stack, because it contains fewer air-spaces than the ice-stack.

By a unit of heat is meant the amount of heat which is necessary to raise 1 lb. of water one degree from the melting point of ice, that is, from 0° to 1° C. The quantity of heat which will raise 1 lb. of water at any temperature one degree, or, *vicê versâ*, the quantity which must be removed from 1 kilogram of water in order to reduce its temperature one degree, is so similar in amount to that amount of heat which we have just described as constituting a unit of heat, that it may be regarded as the same. According to De la Provostaye and Desains, and Regnault and Petit, the latent heat of water may be taken at 79·25, or, roughly speaking, 79 units of heat on the Centigrade thermometer. In order, therefore, to convert 1 lb. of ice at 0° C. into water at 0° C., as much heat is required as will convert 1 lb. of water at 0° C. to 79° C., or to raise 79 lbs. of water at any temperature 1° C. 1 lb. of water at 79° C. will be reduced to 0° C. by 1 lb. of ice after the ice has been melted, or will cool by one degree 79 lbs. of water of any temperature. *Vicê versâ*, 1 lb. of ice at 0° C. in melting cools down 1 lb. of water at 79° C. to 0° C., or will reduce 79 lbs. of water at any temperature by one degree. In these statements no account is taken of the loss or gain of heat due to surroundings.

The specific heat of milk of average chemical composition—water being taken as 1—is, as was stated in § 4, about ·85. In order to cool milk, therefore, there is required only 85 per cent of the quantity of ice that would be required to cool an equal quantity of water.

The question whether it is economical and desirable to use ice-manufacturing machines in dairies has not been properly investigated. According to M. Schrodt's experiments, it would seem profitable to use such machines in very large dairies in towns where ice is unusually expensive to procure, but certainly not in small dairies, or in dairies which can obtain their ice cheaply.

53. Methods of Cream-raising.—Before the days of milk-centrifugal machines, and while the old methods of cream-raising were being perfected, the merits of different methods were often attempted to be tried by comparative tests. In Denmark this was attempted to be done by working on milk of the same origin, churning the cream separated, determining the yield of butter, and regarding as most suitable the method which yielded the largest quantity of butter. This method, although somewhat cumbersome and involving many inaccuracies, had the advantage of not requiring chemical investigation. It is not suited, however, for reliable comparison. The author preferred for this reason, in his comparative experiments, which were likewise carried out on milk of similar quality, to determine the percentage of fat in the milk and the skim-milk, as

well as the weight of the cream obtained, and to calculate what percentage of the entire fat in the milk was obtained in the cream. This percentage number he called the cream-yielding coefficient. This method has been followed by others.

As the cream-yielding coefficient depends not only on the percentage of fat in the skim-milk, but also on that of the whole milk, and on the relative weight of the cream and the skim-milk, it affords an exact indication of the yield of cream in different cases, provided the milk used in the experiments has a similar percentage of fat, and that the relative weights of the cream and the skim-milk remain constant.

The calculation of the cream-raising coefficient is very simple, as the following example will indicate:—

100 lbs. of milk containing 3·4 per cent of fat yielded 20 lbs. of cream and 80 lbs. of skim-milk, containing ·5 per cent of fat.

The total quantity of milk contained, therefore, 3·4 lbs. of fat.

In the skim-milk there remained $\frac{\cdot 5 \times 80}{100} = \cdot 4$ lb. of fat.

In the cream, therefore, there was 3 lbs. of fat.

These 3 lbs. make $\frac{3 \times 100}{3\cdot 4} = 88\cdot 24$ per cent of the total quantity of the 3·4 lbs. of fat.

The cream-raising coefficient is therefore 88·24 per cent; that is, 88·24 per cent of all the fat contained by the milk was yielded in the cream.

In the case of a sample of milk containing the average quantity of 3·4 per cent of fat, and yielding on an average 15 per cent of cream, in the Holstein method, and allowing 36 hours for cream-raising, the cream-raising coefficient throughout the year would average 84 per cent. The skim-milk, therefore, would contain in this case ·64 per cent of fat, and if 97 per cent of the fat in the cream were converted into butter containing 84 per cent of fat, then from 100 lbs. of milk 3·3 lbs. of butter would be obtained, or for every lb. of butter obtained, 30·3 lbs. of milk by weight are used. Under similar circumstances, it will be found in practice in the ice method of creaming, when the cream-raising period lasts for 12 hours, that the cream-raising coefficient on the average of a year will amount to 74 per cent. In such a case the skim-milk would contain 1·04 per cent of fat, and for every 100 lbs. of milk 2·91 lbs. of butter would be obtained. That is, 34·37 lbs. of milk are used for every pound of butter produced.

In all the older methods, creaming was effected through the influence of gravity, which is practically always the same. It is

quite different, however, in creaming milk in centrifugal separators, for in this case the force can be regulated at will within comparatively wide limits. In such a method, the aim is to separate the largest possible amount of the fat, by centrifugal action, which is much more powerful than the force of gravity, and which in the older methods, depending on the force of gravity, was not obtainable. An accurate indication of how far this is effected is furnished by the percentage of fat present in the skim-milk. The creaming coefficient is not an indication of this.

54. **Centrifugal Force.**—One of the common properties of matter is its inertia. This is manifested in a body by the opposition it offers to any change in its motion. Any such change must be effected by force. Inertia acts in such a way, that a body set in motion tends to maintain the direction of its motion unchanged, *i.e.* in a straight line. If a body is forced to move in a circle, in every point of its movement it manifests a tendency to move at a tangent to each point of the circle. The direction, therefore, to which it tends to go has to be changed from point to point. The force which effects this is known in physics as *centripetal* force. It is produced when a body is swung round in a circle at the end of a string by the tenacity of the thread, and in the case of a liquid being put in circular motion in a vessel by the sides of the containing vessel. Since every force requires a counter force, a force which acts in exactly similar but opposite direction, every body moving in a circle is subjected to a force which moves from the centre in the direction of the circumference along the radius, a force exactly similar in its manifestation to the centripetal force. This force is called the *centrifugal* force. The centrifugal force is the force which overcomes the inertia of the material, and represents the resistance offered by a body in motion, to change in its direction of movement, and acts upon every body, moving in a curve, that is, in a line, the direction of which changes from point to point. In § 6 the acceleration ϕ, which the fatty globules experience when they are subjected to the action of centrifugal force, was shown to be capable of being calculated as follows:—

$$1\ \phi = a_1\left(\frac{\delta}{\delta^1} - 1\right) \times \left(\frac{2 \times n}{60}\right)^2 \times u^2 \times r.$$

In which a_1 indicates the factor, representing the inertia, δ and δ^1 the viscosity of the milk-serum, and the butter-fat; n the Ludolph

number, u the number of revolutions of a fatty globule in a minute, and r the radius vector of a globule. From this formula, it is seen that the centrifugal force acting on the fatty globule is in simple proportion to the distance of the globule from the centre point around which the revolutions are made, and increases in quadratic proportion to the revolutionary speed.

55. **The Value of Centrifugal Force for the Creaming of Milk.**—The natural force of gravity, which is universally and at all times freely available, and which was formerly exclusively used in cream-raising, acts with uniformity. Not merely does it require a certain time in which to obtain the best possible results, but even under the most favourable conditions it fails to obtain complete separation of the cream from the milk. Much more perfect separation, and a shortening of the time necessary for cream-raising, can only be effected by the application of a force, which will impart to the fatty globules an impetus far exceeding that given by gravity. This force is centrifugal force. It is not to be had gratis, since its application costs money; but it is at all times easily utilized for the purpose of cream-raising, and can be applied in such a manner that its force exceeds that of gravity to the extent of more than a thousand-fold. It is only necessary to subject the milk, in suitable vessels, to a very rapid rotatory motion. The idea of utilizing this force in dairying, and thereby of curtailing the period for the separation of the cream, does not date further back, it would seem, than the middle of the century, when C. J. Fuchs carried out experiments in Carlsruhe on cream separation by centrifugal force. About 1860 similar experiments were carried out by Albert Fesca, in Berlin, and, in 1864, by Antonin Prandtl, in Munich. It was first demonstrated to be practical in 1877 by the German civil engineer William Lefeldt, in Schöningen, in Brunswick, who, after more than fifteen years of arduous experimentation, succeeded in producing a milk-separator, which, if imperfect, was nevertheless practical. Since 1877 the structure of milk-separators has been improved from year to year, and at present there are quite a number of serviceable separators of different structure known by different names. At present all separators are so arranged that when at work they are fed with a continuous stream of milk, and give out in return separated cream and skim-milk. The utilization of these highly serviceable machines has extended more and more, especially since efficient separators, capable of being driven by the hand, have been devised, and they

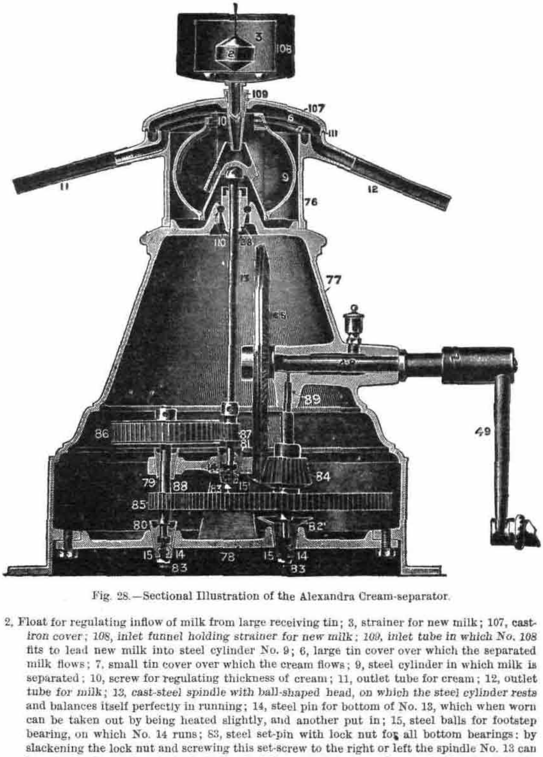


Fig. 28.—Sectional Illustration of the Alexandra Cream-separator.

2, Float for regulating inflow of milk from large receiving tin; 3, strainer for new milk; 107, cast-iron cover; 108, inlet funnel holding strainer for new milk; 109, inlet tube in which No. 108 fits to lead new milk into steel cylinder No. 9; 6, large tin cover over which the separated milk flows; 7, small tin cover over which the cream flows; 9, steel cylinder in which milk is separated; 10, screw for regulating thickness of cream; 11, outlet tube for cream; 12, outlet tube for milk; 13, cast-steel spindle with ball-shaped head, on which the steel cylinder rests and balances itself perfectly in running; 14, steel pin for bottom of No. 13, which when worn can be taken out by being heated slightly, and another put in; 15, steel balls for footstep bearing, on which No. 14 runs; 83, steel set-pin with lock nut for all bottom bearings; by slackening the lock nut and screwing this set-screw to the right or left the spindle No. 13 can be raised or lowered as desired; 84, bevel pinion with 23 teeth, and spur-wheel with 120 teeth; 85, steel pinion with 16 teeth on spindle with leather wheel; 86, leather spur-wheel with 98 teeth and brass flanges each side; 87, steel pinion with 17 teeth on No. 13; 88, steel spindle for carrying leather wheel; 89, steel spindle for bevel pinion and spur-wheel; 79, brass bushing for No. 88; 80, bottom bearing for No. 79; 81, bottom bearing for No. 13; 82, bottom bearing for spindle with bevel pinion; 65, bevel wheel with 108 teeth; 49, handle; 48, handle spindle; 28, main bushing for spindle; 110, india-rubber ring for No. 28, to give elasticity to spindle and prevent vibration with bowl; 111, thin india-rubber ring for cast-iron top, to make same water-tight; 76, cast-iron casing with fastenings and thumb nuts holding cylinder; 77, cast-iron casing holding gearing 78, cast-iron base which can be taken out by unscrewing set-screws and putting the two screw handles sent with each machine in their places.

are every day displacing to a larger extent the older methods of cream-raising. Up till 1886, the only kind of separators used were the larger separators driven for the most part by steam-engines, or horse-power, and in a few cases by other motors, and the application of which only paid in large dairies. For the sake of simplicity the larger machines driven by steam, &c., may be designated power-separators, as distinguished from separators driven by manual power, which may be called hand-separators.

[The illustration in the preceding page of a section of the Alexandra cream-separator, with the explanation of parts, has been inserted by the Translators to assist students in understanding and describing the construction of the separator.]

56. Milk in the Separator-drum.—That portion of the separator which is destined to hold the milk, and which is known as the drum, forms the essential part of every separator, and revolves round a horizontal or vertical axis. Whatever its shape, whether cylindrical or bulbiform, round or pear-shaped, &c., it must always be a rotating body.

When in motion and filled with milk, the force of gravity acting upon the separator-drum may be neglected, when compared with the centrifugal force, which is several thousand times stronger; indeed the force of gravity may be said to be replaced by centrifugal force, and one may assume that the same action and conditions take place in the milk, when shut up in the revolving separator-drum, as take place when milk stands quietly at rest.

Just as milk, which is poured in a slow, steady stream into a milk-pan standing at rest, finds at once the lowest part of the can, namely the bottom, and spreads itself over the bottom in a horizontal layer, and gradually fills the vessel from the bottom to the top, so does milk allowed to flow into a separator-drum, when revolving, find its way with lightning-like rapidity to the most distant part of the drum, and there spread itself out in a ring bounded by a free and almost cylindrical surface, and the drum is thus gradually filled from the outside to the inside, that is, in a direction exactly opposite to that of the direction of the centrifugal force. All separator-drums, without exception, when in motion, and when the milk is allowed to flow in, are thus filled from the remotest part of the wall to the axis round which the drum revolves. It is quite immaterial what part of the drum the milk flows into. Any other method of filling is inconceivable.

Just as milk, standing in a milk-pan at rest, exercises a pressure *on the bottom and sides of the pan, due to the force of gravity*, so precisely milk, in a separator-drum in motion, exercises a pressure on the sides of the drum, which is caused by centrifugal force, and which is proportional to the strength of that force.

In the same way, just as in milk, standing in a milk-pan at rest, *the fatty globules move upwards, in a direction opposite to that in* which gravity acts, so the fatty globules in a separator-drum, filled with milk and in motion, travel in a direction opposite to that of centrifugal force, that is, from outside to inside. In this case, as in the former case, the layer of cream rises to the surface, which in the separator-drum is that portion nearest to the axis of revolution.

57. The Inflow of Milk into the Separator-drum.—The drums of many of the older separators suffered from this disadvantage, viz. that the milk, flowing into them when revolving, was led in on the top of the cream layer, through which it naturally at once sank on account of its high specific gravity. This influenced the amount of fat obtained. Nearly all the drums of the newer separators are so arranged that the milk flowing into them is led in by a suitable arrangement to the inside of the circle of milk, and in this way the very considerable force with which it has to press through the layer of cream is avoided, and the full yield of fat is thereby obtained.

58. The Outflow of Cream and Skim-milk from the Separator-drum.—The outflow of the liquid from a filled separator-drum in motion takes place with considerable energy, and is due to the driving power employed, being in no way connected with the centrifugal force. This force is greater the further the spot is from the revolving axis. Its amount is proportional to the square of the rapidity of the revolving motion at this place, and increases, in a simple regular proportion, with the radius vector of the spot of outflow. In order, therefore, to reduce as far as possible the force with which the liquid flows out, and thus to effect a saving in motive power, the exit for the outflow of cream and skim-milk is chosen as near the revolving axis as can be. The exit for the cream can be placed directly on the surface of the ring of milk, that is to say, as near as it can possibly be to the axis; whereas the exit for the outflow of skim-milk, on account of the higher specific gravity of this liquid, must be placed slightly further back. The skim-milk is conducted either by means of tubes, which run back to the wall of the drum to the surface of the milk-ring, or by means of a special space

made in the drum, and which is only accessible from the wall of the drum, and into which only skim-milk can come. The surface of the skim-milk is thus brought as near as possible to the revolving axis. In the case of such separators as those of Burmeister and Wain, the cream and skim-milk are conducted from the surface, by means of skimming-tubes, to the outside.

59. The Regulation of the Proportional Weights of Cream and Skim-milk in the Separation of Milk by Separators.—In the drum of every separator in use, the amount of cream and skim-milk which flows out must be together equal to the amount of milk which flows in. The proportion of the weight of cream to skim-milk is determined by the rapidity with which the milk enters the separator, and in all separators, therefore, without exception, can be regulated at will by this means when the separator is in motion. By this method of regulation the amount of the cream obtained will be altered, a thing which does not happen with an arranged equable motion. For this reason, in almost all separators there are arrangements whereby it is possible at will to regulate the quantity of cream with a uniform inflow of milk. In the case of the separators of Burmeister and Wain this is effected by sinking the skimming-tube for skim-milk, either deeper or shallower, in the surface of the liquid, a thing which can be very easily effected when the drum is in motion. In the case of most other separators, the necessary precautionary measures should be taken before creaming begins, and while the drum is at rest.

Where the place of outflow for the skim-milk is equidistant, and where the conditions under which the milk flows out are otherwise the same, and the outflow of the cream is not in any way hampered, the more milk that enters the drum in a definite time, the more cream will be given out, the slower will the drum revolve, and the cooler will be the milk which is to be creamed. The first case needs no further explanation. With regard to the second, less skim-milk flows out in a definite time under reduced pressure, and in consequence of this the surface of the milk-ring is slightly moved towards the revolving axis, while in the third case the friction towards the outflow exit is strongly increased, in virtue of which the amount of skim-milk flowing out in a definite time is somewhat diminished.

60. The Size and Reliability of Separator-drums.—The following regulations are deduced from the equations given for calculating the acceleration of separators in § 54:—

(1) In the case of two exactly similar separator-drums making an equal number of revolutions per minute, but one twice as broad as the other, the acceleration in the former at the spot furthest from the centre is double that of the latter.

(2) In the case of two perfectly similar separator-drums of exactly the same size, but one of which revolves at double the rate of the other, that is, has twice the speed of the other, the centrifugal acceleration on the spot furthest removed from the centre is four times as great in the former as in the latter.

From this it will be seen that the action of centrifugal force on the milk may be increased in a double manner, namely, either by increasing the size of the separator or by increasing its speed. Since, however, in the case of doubling the diameter of the drum the action is only increased twofold, but, in doubling the speed, fourfold, the second method will be seen to be the more efficacious. The second method is also to be recommended on other grounds. Large drums are less handy, and are more difficult to work than small ones. Since large masses of metal of a perfectly uniform firm quality are more difficult to be obtained than small masses, there is required for large drums a greater degree of security; in other words, the revolving speed of large drums must be measured with very special care, and this can only be done at the expense of efficiency. Finally, it must be borne in mind that large drums which effect the creaming of large quantities of milk in a comparatively short time require a comparatively large driving power, and that it is more convenient, and generally also cheaper, to utilize a comparatively low driving power for a longer time than a large driving power for a short time. For this reason the use of large drums, such as were formerly largely made, has decreased in the course of time more and more, since they have not been found to be suitable in practice. Separators under 50 kilograms (212 lbs.) in weight are now generally used with drums, and they can only hold when in work a few kilograms (10 to 20 lbs.) of milk, generally between 4 and 8. The smaller of these drums is worked at a speed of 6000 to 9000 revolutions per minute. In the case of most of the separators at present in use, milk which has to be separated only remains a short time in the drum, often not one minute, and rarely more than three.

When the separator is in use, the sides of the drum have to stand very considerable internal strain, owing to the pressure of the milk

and their own weight, and must on that account be very strong. The first and most important quality of every separator-drum is its strength.

61. **Milk-separators at Present in Use.**—Since 1877, the construction of separators has been improved from year to year. While the usefulness of separators has far exceeded the most confident expectations at first entertained, it cannot be asserted that we have yet reached their limits of capability; indeed, it would appear as if we had now reached a point from which a fresh start towards further improvement could be made. Not taking into account some of the separators of antiquated construction, and the separators which, although no longer made, are still in use in various places, we find that there are only five different kinds of separators for power-use, and six for hand-use, employed in German dairies, regarding which the following details may be given.

62. **The Lefeldt Separator.**—In the manufactory of Lefeldt and Lentsch at Schöningen, in the Grand Duchy of Brunswick, seven separators of different sizes and construction are made at present, of which three are worked by steam, one by a winch, and three by hand. Separators for hand-use were first constructed in 1877. The separators worked by power have undergone many changes in their construction from the introduction of the first in 1877 to the one at present in use. From the end of 1879 they have been constructed for continuous use. They are sold under a guarantee, and can be unreservedly recommended. The separators worked by power (fig. 29) require good, pure lubricating oil.

Of exactly similar construction as at present made, only of different sizes, are the three separators, Nos. 0, 1, and 2, for steam-use. At present a new separator is being made in this manufactory, which is to be called the "multiplex". The three separators, Nos. 0, 1, and 2, have cylindrical upright drums closed above and open below, constructed with Siemens-Martin steel, with four continuous flanges, and with a thickness in the case of (0) and (1) of 1·1 centimetres, and in the case of (2) of 1·4 centimetres. The largest internal diameter measures in the case of (0) and (1) 30, and in the case of (2) 40 centimetres. The first-mentioned two have an under opening of 20 centimetres, and the last of 30 centimetres broad. The milk coming in, runs first into a bowl-shaped aperture in the upper portion of the drum, and is conducted hence by means of

canals, which lie behind the layer of cream formed during the motion, into the internal portion.

The cream flows over the surface of the lower circular opening into the lower space of the covering of the drum, and the skim-milk is conducted by means of four tubes, leading almost to the edge

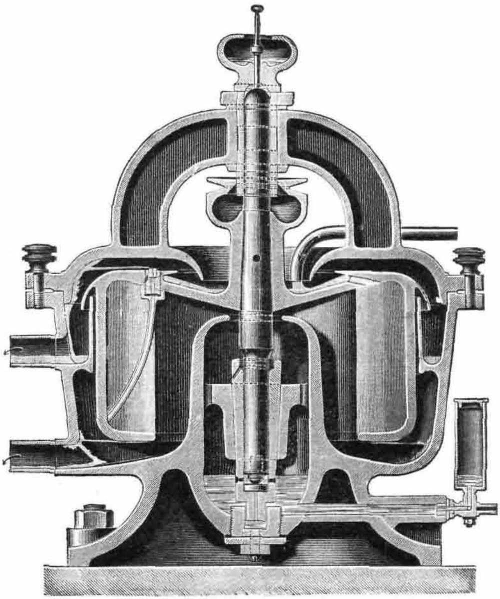


Fig. 29.—Lefeldt's Separator. (Section.)

of the drum and the drum-lid, and passes through the drum-lid into the neighbourhood of the surface of the ring of milk, where it is conducted into the upper covering.

By setting the drum in motion one can make the exit for the skim-milk at the upper end of the tube narrower or wider, so that during the operation more or less cream may be obtained. A hand-

indicator is connected with the well of the drum. After creaming has been effected, the drum, gradually settling to rest, empties itself.

The three separators for hand-use, Nos. ·0, 0, and 1, and the separator for the winch, possess an improved arrangement which

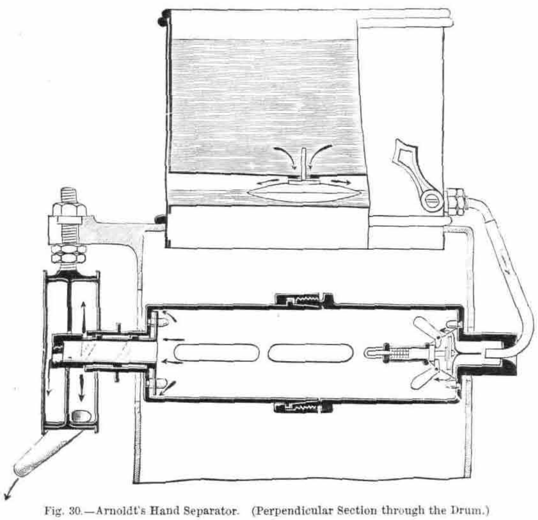


Fig. 30.—Arnoldt's Hand Separator. (Perpendicular Section through the Drum.)

has been devised lately by the senior engineer of the factory, Herr Oswald Arnoldt (fig. 30).

The milk enters through one of the taps, and the cream and skim-milk are conducted away through separated divisions of a tap, which is surrounded by double rings of white metal. Their thickness in the case of No. (0) is exactly ·1, and in the case of the others ·3 centimetre, and the greatest internal diameter in the case of (·0), (0), and (1), and (2) (for winch power) is respectively 5, 9, 9, and 11·5. Further details are contained in the following table:—

Number of Lefeldt Separator.	Weight of Drum with Spindle.	Milk Contents of Drum in Motion.	Number of Revolutions per Minute.	Milk Separated per Hour.	The Cost		Observations.
					of Separator.	of Gearing.	
	Kg.	Kg.		Kg.	M.	M.	
O	27·5	6·0	7,000	600	500	100	Steam-power.
I	32·5	9·0	6,500	900	750	100	"
II	66·0	16·0	6,000	1200	1000	150	"
OO	*3·00*	*0·3*	*10,000*	*60*	*175*	—	Hand power } 45–50 handle-turns per minute.
O	5·50	1·3	8,750	100	250	—	
I	7·25	2·3	8,750	250	500	—	
II	9·25	4·0	8,750	400	600	100	Winch.

63. Separators made by the Separator Co., Stockholm.—This company is represented in Germany by the Bergedoff Iron Co., in Bergedoff, near Hamburg, and makes in all, at present, fourteen different separators for machine and hand use. They may be divided into separators of the De Laval and the Alpha types.

(*a*) *De Laval Separators.*—Of these there are at present two kinds. The De Laval separators have in course of time been very much improved. The first was introduced into Germany in 1879, and was used at the co-operative dairy at Hamm, in Hamburg. It was the first employed to do constant work in Germany. Its drum had three independent parts, which were screwed together, and were made tight with rubber rings. In the year 1881 the arrangement of the drum received its first improvement, which consisted in replacing the three independent parts by one piece, consisting of a cup-like box provided with flanges. In 1883 the drum received the simple form which it still retains. In the year 1886 Dr. De Laval invented his steam-turbine, which he

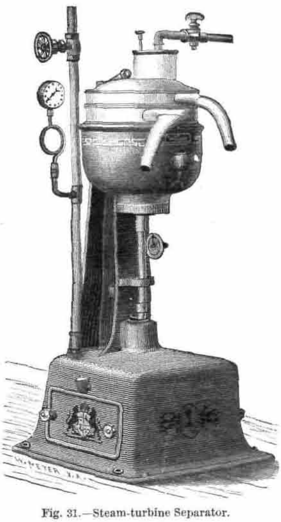


Fig. 31.—Steam-turbine Separator.

applied directly to the separator, and by means of it he imparted to the creaming of milk by centrifugal machines a simplicity that had been previously undreamt of. The first steam-turbine separator, worked in Germany, was used in the co-operative dairy at Elmshorn, in Holstein, where it was placed in the beginning of the year 1887. By means of the turbine the use of steam-engines and the customary connections for securing speed could be dispensed with. Thus was effected a large saving of plant, of capital, of space, and of lubricating oil, while the efficiency of the work was increased. In order to set it in motion, all that is necessary is to press the cock gradually upwards, which connects the steam with the turbine. The De Laval separators (figs. 31 and 32) require, therefore, according to the claim of the manufacturer, steam of only 45-lbs. pressure, and the Alpha, steam of only 30-lbs. pressure. Nevertheless it is advisable to use steam of 60 and 45 lbs. pressure respectively.

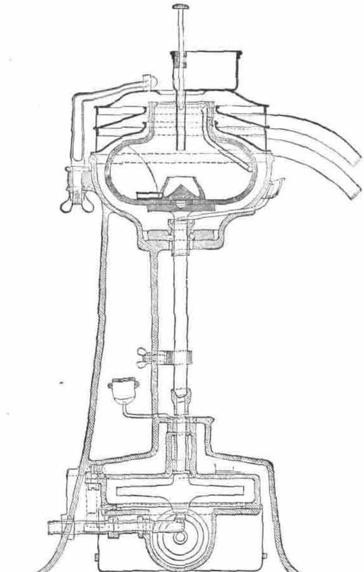


Fig. 32.—Perpendicular Section of Steam-turbine Separator.

The De Laval separators are especially characterized by the simplicity of their structure and their serviceableness, and by the fact that they are not easily susceptible to disturbing influences. They are excellently suited for private dairies in which creaming is necessarily left to unskilled workers. They have stood the test of

time, and can be unreservedly recommended. So also can the Alpha

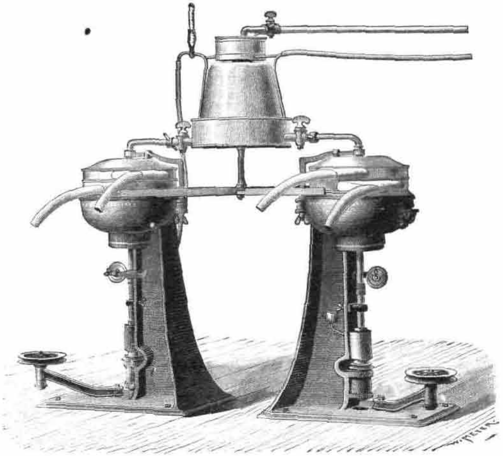


Fig. 33.—Two Laval Separators with Milk Warmer.

separators, which have been well tried, and which have given great satisfaction wherever they have been used.

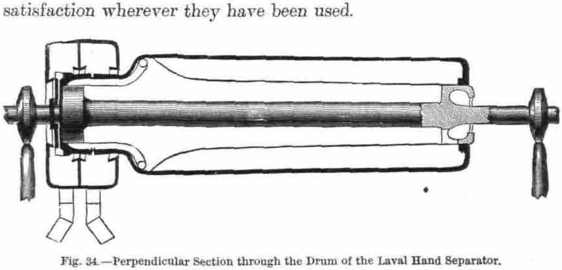


Fig. 34.—Perpendicular Section through the Drum of the Laval Hand Separator.

The upright drums, open at the top, and ·9 cm. broad in their broadest place, are made out of malleable cast steel, have a bulbous form, a cylindrical-shaped neck, 11·2 centimetres in width, and a large internal diameter of

28·8 centimetres, and a continuous flange inside. In the case of No. the drum is somewhat higher. The milk which comes in falls throug the top opening of the drum into a cup 5·2 centimetres wide, restin upon the foot of the drum, and flows from this to a tube under the layer o cream, formed during the operation. The cream runs outwards through a narrow, shallow slit in the side of the neck of the drum, and the skim-milk through a tube leading up from the widest part of the drum, then through a small opening about half-way up the neck of the cylinder, which can be set, when the drum is at rest, either narrower or wider, and of course each liquid by itself runs into a special circular-shaped receiver at the top of the cover. A simple indicator, which is placed in the well, renders it possible to determine the rapidity of the revolutions of the drum per minute.

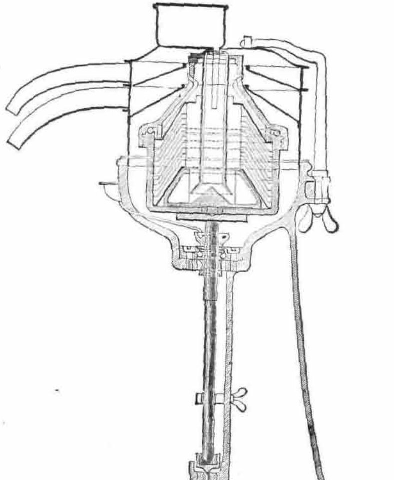


Fig. 35.—Alpha Separator No. 1. (Perpendicular Section.)

(*b*) *De Laval Hand-separators.*—Dr. De Laval devised the first useful hand-separator in 1886. At present two such machines are made, the separator (K), which has a horizontal cylindrical drum, and the Baby separator, which has a vertical cylindrical drum. The drums of both these separators have short cylindrical necks,

two continuous flanges in the inside, and a thickness of ·25 centimetre.

The hand-separator (K) has a horizontal drum, which, in the widest place in the inside, is 10·7 and in the neck 6·7 centimetres wide. The milk enters at one side of the drum, and on the other it passes through an opening in the neck of the drum, the skim-milk being separated by means of two white-metal tubes, which surround the neck of the drum. One of these tubes, when the drum is at rest, can be adjusted either narrower or wider.

The Baby separator is, in essential points, of similar construction to the separators for machine use. The drum is internally 9·8 centimetres, and round the neck 6·6 centimetres wide, and is set in motion by means of a toothed wheel.

Both separators attain their maximum speed when the handle makes 40 revolutions per minute.

We have to thank the Bergedoff Iron Works for the following details:—

Number of Separator. De Laval.	Weight of the Drum with Spindle.	Milk Contents of Drum in Motion.	Number of Revolutions per Minute.	Milk Separated in the Hour.	The Cost		Observations.
					of Separator.	of Gearing.	
	Kg.	Kg.		Kg.	Marks	Marks	
A I	20·5	6·0	7000	400	550	100	Machine-driven.
A II	25·0	8·2	7000	600	800	100	"
E I	20·5	6·0	7000	400	1100	—	Steam-turbine.
E II	25·0	8·2	7000	600	1500	—	"
K	4·5	1·6	7000	150	550	—	Hand-use (horizontal drum).
Baby	3·5	0·8	6400	50	260	—	Hand-use (vertical drum).

(*c*) *Alpha Separators for Machine Use.*—These have been known in Germany since 1890, and at present three different sorts are manufactured, viz. Nos. (1), (2), and the Alpha pony (fig. 35).

(*d*) *Alpha Separator for Hand Use.*—These at present in use are of three numbers: Alpha K with horizontal, and Alpha B, as well as Alpha S or Baby, with perpendicular steel drum (figs. 36, 37, and 38). The drums of these three machines attain their most favourable speed when the handles make forty revolutions per minute.

64. The Separators of Burmeister & Wain.—As early as the year 1872, the well-known chemist, Storch, of Copenhagen, drew the attention of Danish agriculturists to experiments carried out by

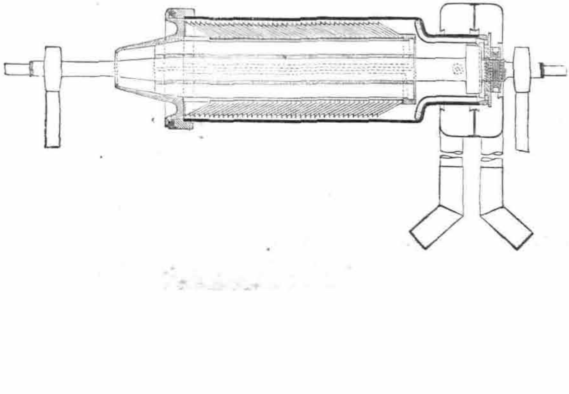


Fig. 36.—Alpha Hand-separator (K). (Perpendicular Section through the Drum.)

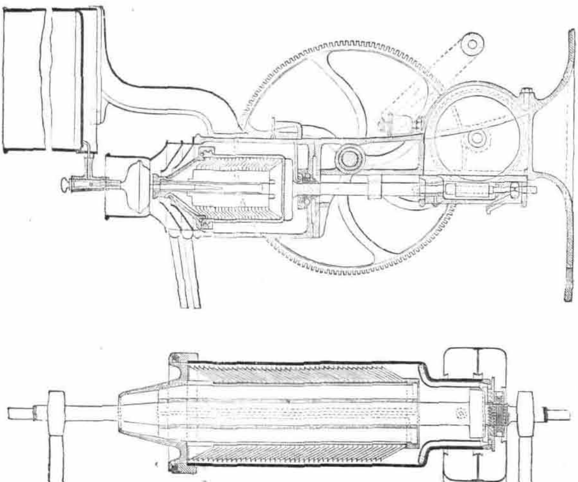


Fig. 37.—Alpha Baby Hand-separator. (Perpendicular Section.)

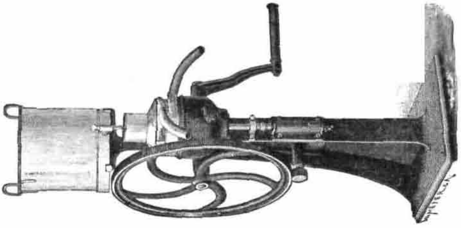


Fig. 38.—Alpha Hand-separator (B).

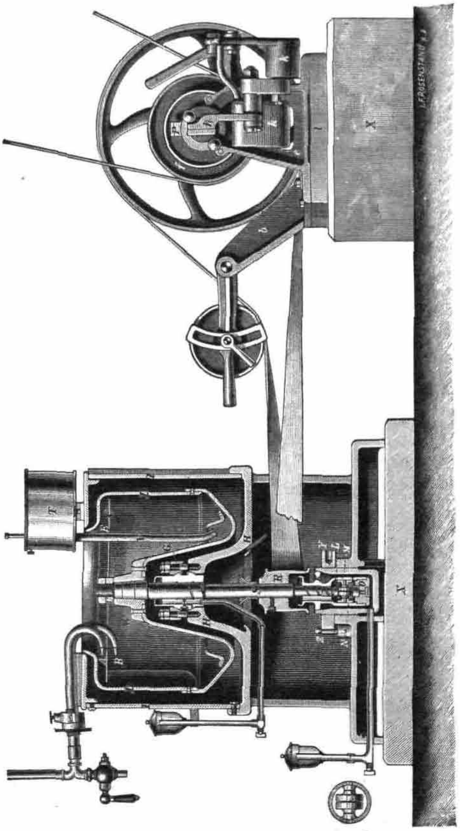


Fig. 39.—Danish Centrifugal Cream Separator (Burmeister & Wain). (Perpendicular Section.)

Antonine Prandtl in Munich, regarding the separation of cream from milk by centrifugal force. In consequence of this, in 1873, experiments were conducted with the Eimer centrifugal separator, and an engineer, Mr. P. J. Winstrup, undertook the construction of a milk-separator. He made experiments in 1878 with a separator constructed by himself in the dairy of States-Councillor Valentine in Jeddesdal, and in 1878 brought out a workable separator, which, however, was not largely adopted in practice. In the meantime, several other engineers, particularly L. C. Nielsen, had been occupying themselves with the construction of milk-separators. In the year 1878, there had been set up on a farm near Copenhagen a separator for regular work, Kongen's Nytorf separator No. 10, devised by L. C. Nielsen, and made in the manufactory of Peterson Brothers in Maglekilde, near Roskilde. In the course of a year it was distinctly improved, and in the year 1879 it was changed into the form which it at present possesses, and quickly became known under the name of Nielsen & Peterson's patent separator. In the year 1881, the Engineering and Ship-building Co. of Burmeister & Wain bought the patent of 1878, and since that time the separator has been known as Burmeister & Wain's separator (fig. 39). It has been extensively used, especially in Denmark itself. It is warranted, and

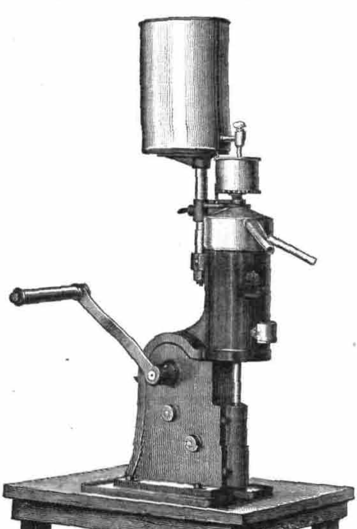


Fig. 40.—Hand-separator (Burmeister & Wain).

can be unreservedly recommended. At present four other separators are used or made, the bowl-separators (A) and (B) for machine use, the separators (X 1), (A), and (X 2) for hand use (figs. 40 and 41). The separators of Burmeister & Wain are characterized by their elegant construction and their smoothness of working. They allow the quantity of cream to be regulated during the revolution of the drum, and alone among separators offer the extremely and universally valuable advantage, that it is possible, if desired, to pump up the cream and the skim-milk several metres in the ascending tubes. Cream and skim-milk gush out at the end of the exit tubes more strongly than is the case with other separators. Owing partly to their fine construction, they require to be carefully and intelligently handled.

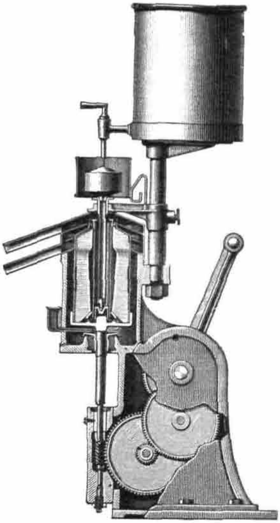


Fig. 41.—Burmeister & Wain's Hand-power Separator. (Perpendicular Section.)

They are provided with a self-acting security arrangement, which prevents an increase of the speed above the regulated degree. It may be added that these separators may be used in the simplest manner for preparing emulsions of oil and skim-milk for calf feeding.

The following are the dimensions of a number of separators made by Burmeister & Wain:—

Number of Separator. Burmeister & Wain.	Weight of the Drum without Spindle.	Milk Contents of Drum in Motion.	Number of Revolutions per Minute.	Milk Separated per Hour.	Cost of Separator.		Observations.
	Kg.	Kg.	Kg.	Kk.	Marks.	Marks.	
A	120	58·0	2700	1400	835	425	
A A	120	58·0	2700	1400	835	425	
B	54	16·5	4000	700	467	288	
X 1	3·25	1·25	7200	150	285	—	
X 2	3·75	1·66	7200	200	400	—	

65. The Victoria Separators.—These are made in the works of Messrs. Watson, Laidlaw, & Co., Glasgow, and have been known since the end of the year 1879. Six different sizes of these separators,

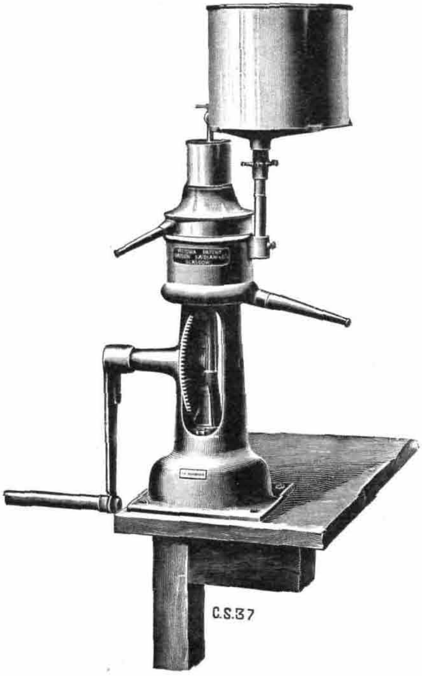


Fig. 42.—Victoria Hand-power Cream Separator.

known as (1), (2), (3), (4), (5), (6), have been used in Germany (figs. 42 and 43). The first three are for hand use, the last three for machine use. Up till now these separators lack an arrangement for regulat-

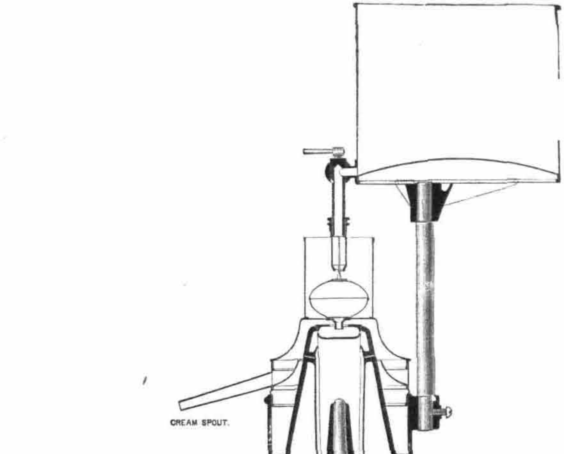


Fig. 43.—Sectional View of Victoria Hand-power Cream Separator.

ing the amount of cream to be obtained from an equal flow of milk.[1]

66. **The Balance Separators.**—The discoverer and first patentee of this separator, which was made known at the beginning of 1888, was a Dane, whose *nom de plume* was Musician. In February, 1888, a similar separator under the name of the Nilson separator was made by the firm of Mot & Co. of Paris, and in the same month a balance separator supplied by the Carl Peter Co. was used on the estate of Emken Dorf in Holstein. The construction of the balance separators has undergone, up to the present time, a number of changes, but they have been comparatively little tried in practice. The Carl Peter Co., which has acquired the patent, makes these separators of six different sizes, three for machine use, with drums made of hardened steel, and three for hand use, with drums made of hard hammered copper (fig. 44).

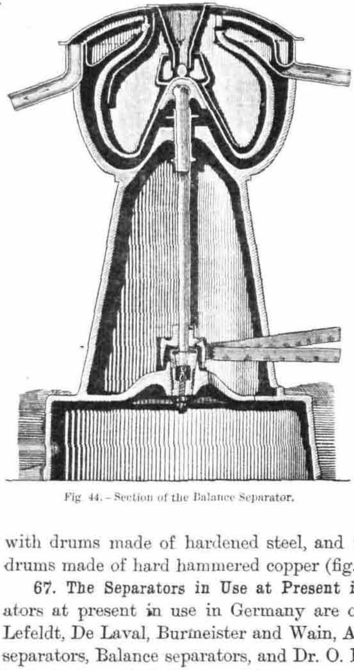


Fig. 44.—Section of the Balance Separator.

67. **The Separators in Use at Present in Germany.**—The separators at present in use in Germany are of seven types—those of Lefeldt, De Laval, Burmeister and Wain, Alpha separators, Victoria separators, Balance separators, and Dr. O. Brown's separators. The first six types include several large separators of different sizes for

[1] Messrs. Watson, Laidlaw & Co. point out, on the other hand, that in their machine the proportionate yield of cream is altered by increasing or diminishing the supply of milk, which can be done without stopping the machine. They claim that this method of obtaining thick or thin cream is advantageous, as it obviates the necessity for having any special arrangement in the drum for this purpose.—*English Editors.*

power use, as well also as for hand use. The separators of Dr. O. Brown are hand-separators. Altogether there are used in German dairying 41 separators, 22 for power use and 19 for hand use. The separators of De Laval and Burmeister and Wain are warranted. Their merit is established. The Alpha separators have also been proved to be satisfactory, from the results of many exhaustive experiments which have been carried out on them. As to the capacity of the remaining separators, further reliable experiments and tests are required to enable a correct judgment to be formed, and to prove their practical value.

68. The Best Separators.—The value of a separator is determined chiefly, though not exclusively, by its capacity for work. This is best measured by the quantity of milk which it can cream in an economical manner, at a uniform rate of speed, and at a fixed cost per hour, when fed with a regular supply of warm milk at 30° C., the skim-milk to contain an average percentage of fat of ·25 per cent. A separator possesses, therefore, the largest capacity for work which creams in an hour, under the above conditions, the largest quantity of milk. Which is the best separator at the present time it is impossible exactly to say. In the middle of the eighties, one might assert that the three at that time most in use differed very little from one another. Among the six different separators for power use which are at present used, much difference, however, exists, since a new advance would appear to have been made in the perfecting of separators, which in time may permit us to await again a certain settlement in the capacity of the different separators. The most efficient separators are not always the best. The best separators may be described as those that are best suited, from a technical and economical point of view, for the special conditions under which they are to be used. Whether a separator will ever be found which will prove to be the best under all conditions, it is impossible to say. It is also very questionable whether circumstances may not exist in which, where very slight differences in their capacities exist, the less capable of two separators may not be preferable, since it may possess certain advantages and conveniences which, although they appear to be of little importance, have yet a material value in the circumstances in which they are used.

69. The Cream-raising Coefficient in connection with the Use of Separators.—As has already been mentioned in § 53, the extent to which cream has been separated from milk by centrifugal

force is best ascertained by the percentage of fat in the skim-milk obtained. Considering the efficiency with which separators at present do their work, one is justified in demanding that in dairies where separators are in use the coefficient of cream-raising should be such that a percentage of ·2 to ·3—on an average ·25—of fat is obtained in the skim-milk.

It is only under very exceptional circumstances that the skim-milk obtained by separators contains as little as ·1 per cent of fat. Just as in the case of whole-milk which has been evaporated down to dryness, the fat is less easily extracted by ether, so it is found that, in the gravimetric determination of fat in skim-milk, if not done with care, the percentage of fat may quite easily be placed too low. Examples of skim-milk obtained by separators under ordinary conditions containing less than ·15 per cent, or much less than ·1 per cent of fat, are, therefore, to be viewed with suspicion.

70. The Conditions which Influence the Cream-raising Coefficient in connection with Separators.—The coefficient of cream-raising obtained with milk-separators depends on the following conditions:—

(1) On the strength of the centrifugal force used to separate the milk, or on the rapidity of the revolutions of the drum. As has already been pointed out, the centrifugal force increases with the square of the number of revolutions made by the drum in a minute. If the drum of a separator does not revolve quickly enough, or up to the required speed, much fat will remain behind in the skim-milk, which might, with greater care, be easily obtained in the cream.

(2) On the time during which the milk is submitted to centrifugal force, or on the quantity of milk which is creamed per hour. The more milk that is creamed in a given time, the less favourable will the coefficient of cream-raising be.

(3) On the temperature at which cream-raising takes place. The warmer the milk the better does it cream. From 5° to 25° C. upwards, the percentage of fat in the skim-milk rapidly decreases, and from that temperature always more and more slowly up to the boiling point of milk.

These three conditions are of enormous importance, and since they are always under control, it may be said that the success of cream-raising depends on the art and method in which separators are worked. It is further influenced by—

(4) The construction and nature of the separator. For example,

whether the milk-ring in the drum is more or less strong, whether the drum works regularly and quietly, and whether the machine can be conveniently and simply worked.

(5) On the special properties of the milk which is to be separated. Under ordinary conditions, milk brought from a distance, or lazy milk, or boiled milk, is less easily creamed than fresh milk of ordinary properties. Perhaps also milk, very rich in fat, is less perfectly creamed than milk containing an average percentage of fat. These conditions are insignificant, and hardly possess any importance in practice. They have a perceptible influence in properly regulated separators only if the creaming takes place at a temperature under 20° C.

The numerous experiments carried out during the years 1877–1885 at Raden, with different separators, were the first which distinctly showed that creaming is more effective the quicker the separator-drum revolves, and the warmer the milk is which is to be creamed, and the smaller the quantity of milk that passes through the drum in a given time. They showed, however, that between the percentage of fat (f) in the skim-milk on the one hand, the rapidity (u) of the drum which determined, on the other hand, the quantity of milk (m) creamed in an hour, and the temperature of creaming (t), a certain regular relation existed. Numerous detailed calculations, which the author has made on the basis of a large number of single experiments, show that the truth is very nearly obtained by assuming that the percentage of fat in skim-milk (f) is inversely proportional to the square of the number (u), denoting the revolutionary speed, and directly proportional to the square root of the number (m), denoting the quantity of milk creamed in an hour. The relation of the number (f) to the temperature of cream-raising (t) was found, if (f), denoting the fat percentage of skim-milk at 40° C., lay between the limits of 13° and 40° C. by the equation—

$$f = f_1 \times 1{\cdot}035^{40-t}$$

and this yields also

$$f = c \times \frac{\sqrt{m}}{u^2} \times 1{\cdot}035^{40-t}$$

(c) indicates a constant factor, which has been obtained for each separator by means of exact experiments. If the value of this factor has been carefully fixed for a definite separator, it is easy, as has been elsewhere shown, by the author, to find the exact value of (f) for all values of (u) between $\frac{1}{2}$ (u') and 2 into (u'), for all values of (m) between ($\frac{1}{2}$ m') and (2 into m'), and for all values of (t) between 20° and 40° C. In the case of some

separators, the author obtained better results if he substituted, in the above formula, for the square root of (m), simply (m). The above formula was well suited for the three separators, which were almost exclusively used up till 1888. As to whether it also suits the Alpha, the Balance, and the Victoria separators in their present form, the author has not yet been able to make investigations.

In order always to obtain satisfactory results, the following points have to be carefully observed in practice:—

(1) That the drum should always revolve at the prescribed rate; to permit it to revolve more quickly may be dangerous (see § 60), and if it does not revolve sufficiently quickly there may be a considerable loss.

(2) That the milk to be creamed every day should be of suitable quantity, and should enter at as uniform a rate as is possible per hour.

(3) That the milk during the whole period of creaming should possess the proper temperature.

(4) That the separator should always be in good order, and should be carefully lubricated with good oil.

71. The Supervision of the Revolving Rate of the Drum.—Formerly the rate of revolution of the drum was shown by an indicator, which was either in permanent connection with the well of the drum, or was pressed against the head of the well from time to time, in order to show if the drum were revolving at the prescribed rate. This indicator showed how many revolutions per minute the drum made during the time of observation. For ordinary use, however, it is unnecessary always to know the exact number of revolutions per minute. It is sufficient to know whether the drum is revolving at the prescribed speed, or whether the speed is increasing or diminishing. This is shown by the new indicator, devised by Dr. O. Brown, of Berlin, which may be directly or indirectly placed in all separators in a very simple way. As the success of creaming is influenced, to a large extent, by the rate at which the separator drum revolves, work should never be carried on without an indicator.

In the case of hand-separators, it is often sufficient to regard the revolution of the handle as an indication of the prescribed number of revolutions per minute. This may be effected without using an indicator by utilizing the swing of a swinging pendulum, the number of swings of which per minute correspond exactly with the desired number of the revolutions of the handle. No doubt it is certain, in the case of hand-separators, that the drum assumes the

proper revolving rate only where the handle is properly turned. The hand-separators whose drum is turned by means of friction (the hand-separators with falling drums, the Arnold, De Laval, and the Alpha hand-separator K) should not be used without an indicator.

For exact scientific experiments indicators are necessary, such as those of Schäffer and Budenberg—indicators which record exactly the number of revolutions made by the separator-drum throughout a comparatively long period.

72. The Supervision of the Quantity of Milk Creamed per Hour.— Very different quantities of milk may be creamed per hour, in different separators, and variable quantities of skim-milk, containing different percentages of fat, may similarly be obtained. In a well-ordered dairy the aim is to obtain daily an equal quantity, viz. the largest possible quantity of fat. In order to obtain this, the milk has to be poured into the drum at an equable rate; and secondly, the quantity of milk creamed should be creamed in such a way that the desired coefficient of cream-raising should be obtained. The first condition can be satisfied, at any rate approximately, by the use of vessels with floats. A good vessel should also be arranged in such a way that one can limit the rate at which the milk runs out, so as to be able to increase or diminish the quantity running out in the course of an hour.

The measure of the rate at which milk runs out is discovered by estimating the amount of milk which is daily creamed per hour. The percentage of fat in the skim-milk is also determined. Should it be found that the coefficient of creaming is unsatisfactory, the rate at which the milk runs in ought to be diminished, until the skim-milk flowing away shows a percentage of fat of about ·25.

The amount of milk creamed per hour is determined as follows:— When the drum has obtained its full speed, and creaming is ready to be started, the hour, minute, and second are noted, at which the cock of the warmer or of the collecting vessel is opened; and again, the time at which the last of the milk passes through the cock. The interval is that during which the whole quantity of milk runs through the drum. For example, if from 6·17 till 9·32—that is, 3 hours 15 minutes, or 195 minutes, 260 kilos. exactly of milk passed through the drum of the separator, the amount of milk which would be creamed in an hour would be

$$\frac{2600 \times 60}{195} = 800 \text{ kilos.}$$

In order to obtain a regular flow of milk into the drum of a separator, one may use a feeding vessel (floating) such as that made at the works of Lefeldt and Lentsch. It was first exhibited at the second German Dairy Exhibition in Munich, in October, 1884, and is used in many dairies.

73. The Regulation of the Temperature in the Separation of Milk.—As the percentage of fat in the skim-milk is very largely influenced by the temperature at which the creaming of the milk is effected, it is quite inadmissible to cream milk at the changing temperatures which it possesses from day to day. Creaming should rather be effected at a temperature at which it will be maintained throughout the whole year. This temperature practical experience has shown to be between 25° and 35° C., on an average 30° C. In the event of one wishing to cream the milk at 70° to 80° C., for the sake of sterilizing it, if a definite temperature has been determined, it ought to be rigorously maintained; and that it varies as little as possible during creaming should be determined by frequently testing it with the thermometer. In order to warm milk to the right temperature warmers are used, which are placed between the milk-collecting and milk-feeding vessels, and these are best heated with steam.

The cylindrical warmer containing a simple stirrer without brushes, or warmers in which the milk is allowed to flow over a hot, ribbed surface, have been found in practice to be successful. Good warmers should be arranged, as they generally are, so that the milk may quickly gain the desired temperature, and when this is done the milk should be conducted without any unnecessary delay into the drum. The shorter the time required to raise the milk from 25° to 35° C., the more certainly can a cream and skim-milk of good keeping quality be relied on. If it be desired, in order to avoid the cooling of cream and skim-milk, to cream the milk at 15° C., the flow of the milk must be correspondingly diminished, and the separation of the milk carried on for from 5 to 8 minutes longer. The increased expense by such treatment in dairies where steam is used, is generally more than that incurred in warming the milk, and in cooling the cream and skim-milk.

R. Backhaus, the director of the dairy in Fulda and Lauterbach, has recently recommended that the sterilizing of the milk should be combined with separating it in such a way, that the milk, at a temperature of 70° to 80° C., coming out of the sterilizer, is immediately conducted into the separator-drum. Backhaus has been working for a year already at this process, and he affirms that it gives the best results. This process has also been in operation in Kleinhof-Tapiau since the middle of February,

1892. If a percentage of fat in the skim-milk of ·25 per cent be regarded as satisfactory, certainly distinctly more milk can be creamed per hour at these high temperatures than at 30° C., and in this fact another advantage is to be found.

74. The Regulation of the Relative Quantity of Cream and Skim-milk in the Use of Separators.—With all separators a larger or smaller quantity of cream in proportion to the skim-milk can be obtained at the will of the worker. All that has to be done is to increase or diminish the amount of the flow of the milk to the drum. In this, however, the degree of creaming varies, a thing that ought not to be permitted in well-regulated work. For this reason, the quantity of cream obtained from an equal supply of milk ought to be able to be regulated at will. In the drums of all separators, with the exception of the Victoria separator, the necessary apparatus is supplied. In the separators of Burmeister and Wain, arranged for power use, the regulation is effected during the flow, and in the other separators such precautions as are necessary must be taken while the drum is at rest, in most cases before the commencement of the creaming. *If the speed of the flow of milk* does not change, it does not exercise the slightest influence on the percentage of fat in the skim-milk, whether 15, 20, or 25, or still higher percentages of cream be taken. It is only when the quantity of cream is less than 10 per cent of the total weight of the milk, that the cream is imperfectly separated in the case of some separators. *The cream is obtained thicker and richer in fat the smaller the* quantity. It is not to be recommended to take less than 10 per cent of the weight of milk, while over 20 per cent should only be taken if there is some special object, since skim-milk would be lost. As a rule it is desirable to obtain 15 per cent to 20 per cent of cream.

If there be indicated by (f) and (f_1) the percentage composition of the fat of milk and skim-milk, and by (r) and (b) the relative proportions of cream and butter obtained from 100 parts of milk, the percentage of fat in the cream (x) will be exactly found by the following equation:—

$$x=\frac{100\times(f-f_1)}{R}+f_1,$$

and approximately by the equation:—

$$x=\frac{B\times 86}{R}.$$

If milk containing 3·3 per cent of fat be creamed at 30° C., the cream will contain, according as it forms 15 or 20 per cent of the milk, 19 to 20 per cent, or 14 to 15 per cent of fat.

75. **Condition of Cream and Skim-milk from Milk-separators.**—When the work is carried out intelligently, the creaming of milk by centrifugal force exercises a favourable action on the condition of the cream and skim-milk; and it has long been proved that it is easy to obtain butter which comes perfectly up to all requirements from cream obtained by means of separators. The very small loss in material which milk suffers in creaming, by a small portion of the nitrogenous matter passing into the so-called separator mud, is, it would seem, in every respect, and especially so far as the condition of the skim-milk is concerned, quite unimportant. The obtaining of fine butter is dependent upon the fulfilment of the necessary condition, that the cream, coming out of the separator-drum, should be cooled down as quickly as possible, to 5° C., by the application of ice. If the cream be exposed for any length of time at the temperature at which it leaves the drum its condition suffers, as does that also of the butter into which it is made. Experience has shown that it is not sufficient only to cool the cream partially to 12° C. For cooling, cream-coolers of different construction may be used. Refrigerators which have been largely used and tested are the Lawrence coolers (fig. 45)—coolers in which the cream is cooled by being slowly passed over ribbed and comparatively large metal surfaces in a thin stream, and the Laval cream-cooler (fig. 46). Skim-milk, unless for use, ought to be cooled down, after its removal from the drum, to at least 10° to 14° C. It is admirably suited for use as human food, or for feeding calves and pigs. As it is very poor in fat, however, it forms only a one-sided kind of food.

Fig. 45.—Lawrence's Refrigerator.

Skim-milk, containing only ·25 per cent of fat, is not, as a rule, adapted for making into skim-milk cheese. Nothing is easier, where there is a demand for skim-milk cheese, than to so regulate creaming that a skim-milk is obtained with the desired higher percentage of fat. *Skim-milk, when Pasteurized, no longer possesses the property of yielding a coherent coagulation under the action of rennet.*

There can hardly be any dairies in which throughout the whole year there will be a supply of such cold water at command that the requisite quantity can be safely enough provided. For that reason ice cannot be dispensed with in dairies, and the necessary supply must be provided.

Fig. 46.—Laval Cream-cooler.

The precaution of cooling the cream quickly and thoroughly is one which is apt to be least recognized in practice, although it is known by thousands of observations that cream at warm temperatures quickly loses its pure taste. It is only by a happy chance that cream, which has been kept for some time at a high temperature, yields good butter.

If creaming be effected at 30° C., it will be sufficiently near the necessary quantity to give, for every litre of milk which passes through the drum, ·2 to ·3 kilograms of ice.

76. The Proper Working of Centrifugal Machines in Dairies.—Success in dairy management requires that there should be no failure to provide sufficient and well-arranged rooms, and that the staff on the one hand are not overworked, and, on the other hand, that they observe the greatest care and punctuality.

In every good and well-regulated dairy, separators are used, and in those in which cheese is not made there should be at least ten rooms. First, a room for the milk samples; second, for cleaning the vessels and utensils; third, for separators and their necessary gear; fourth, for keeping milk, skim-milk, and cream, with an arrangement for cooling; fifth, for butter-casks; sixth, for cream-souring and the working of butter; seventh, for the storage of ice; eighth, for coal storage; ninth, for steam-engines; and tenth,

for keeping butter for sale. If space be deficient, and if it be required to limit the room, it may be necessary to unite the milk samples' room and the room in which the cleaning of the vessels goes on, and to put the butter-casks and the separators in one room; but the room for the separators and butter-casks must be large and roomy. Especial care should be exercised in the choosing of the situations of the rooms for keeping the milk, skim-milk, and cream, and for cream-souring and the working up of the butter. The last-mentioned room must be capable of being heated.

Before creaming is begun, the separators should be examined daily to see that they are in good working order. During creaming, the supply of milk, and its temperature, as well as the rate at which the drum revolves, should be carefully observed for five minutes. It is sufficient to steam the drums of the separators, along with the other apparatus, once a day, and to rinse them out with hot and cold water. Furthermore, they should be treated at least twice a week with a warm dilute solution of soda. The following points ought to be carefully observed:—

(1) If a separator is not in good working order it ought on no account to be set in working motion.

(2) The drums of separators should be slowly and gradually brought up to the required revolving speed.

(3) When, during motion, the driving-belts slip off the wheel, no attempt ought to be made, under any conditions, to put them on while the wheel is in motion. The engine must be stopped before the belt can be put right.

(4) During the time the machine is in motion the hand ought not to be laid on it, and the drum should not be touched. This habit may be very easily acquired in the case of some separators. In using the separators of Burmeister and Wain, no attempt ought to be made to remove or to replace a dish while the machine is in motion.

(5) If, during the motion of the machine, anything unusual happens, the driving power ought to be at once stopped, and the same ought to be done if the drum stops.

(6) Great care ought to be taken when the machine is in motion not to come near the running belt.

In most dairies in which separators are used the separators are only used once a day, and the morning and evening milk are creamed together, perhaps also the forenoon's milk of the previous day, which has been kept overnight in a special room at a temperature of under 10° C. Practical experience has shown that the necessary attention can no longer be paid

Number

Place................ ......Separator Table, from..........to...........18 Kept by....................

1895, March.	Quantity of Milk.	Time.	Temperature °C.			Revolutions per Minute.	Creamed in the Hour.	Actual Yield.			Percentage Yield.			Percentage of Fat.		Temperature of Room.
	Lbs.	Min.	Milk.	Cream.	Skim-milk.		Kg.	Cream.	Skim-milk.	Loss.	Cream.	Skim-milk.	Loss.	Milk.	Skim-milk.	°C.
Sunday,......5	5,708	105	72	15	6	5,630	1631	956	4,723	29	16·75	82·74	·51	3·27	·19	8·5
Monday, ...6	2,579	48	72	13	4	5,610	1612	403	2,163	13	15·63	83·87	·50	3·50	·17	8·0
Tuesday, ...7	2,596	52	76	15	5	5,590	1498	441	2,142	13	16·99	82·51	·50	3·45	·12	7·5
Wednesday, 8	2,870	55	75	13	5	5,580	1565	457	2,399	14	15·93	83·58	·49	3·33	·13	9·0
Thursday,...9	4,108	77	74	16	7	5,590	1601	735	3,352	21	17·89	81·60	·51	3·42	·15	9·5
Friday,.....10	3,142	60	74	14	4	5,620	1571	484	2,642	16	15·41	84·08	·51	3·48	·16	8·0
Saturday,..11	3,261	62	75	12	4	5,580	1578	536	2,709	16	16·44	83·07	·49	3·35	·13	12·5
Total, ...	24,264	459	518	98	35	39,200	...	4012	20,130	122	...	...	...	23·80	1·05	63·0
Average,...	3,466	66	74	14	5	5,600	1586	573	2,876	17	16·54	82·96	0·50	3·40	0·15	9·0

number of the separators in use ought to be taken into account. In every well-conducted dairy, exact details ought to be noted daily and entered into suitable tables, with regard to all the more important conditions, and also with regard to the success of the work. By means of such details, which permit of the slightest irregularities and their causes being clearly traced, the work attains a high measure of efficiency. The nature of these details may be best illustrated by the table on p. 151.

If, for example, in the week under discussion, 12,132 kilos. of milk have been treated and 450 kilos. of butter obtained, there would be used for every kilo. of butter 26·6 kilos. of milk, or for every 100 kilos. of milk 3·75 kilos. of butter. The quantity of butter (B) which, under ordinary treatment, can be obtained from milk, with an average fat percentage (f), can be found by the following simple formula:—

$$B = 1{\cdot}16 \times f - {\cdot}25\text{; e.g. } B = 1{\cdot}16 \times 3{\cdot}4 - {\cdot}25 = 3{\cdot}69 \text{ kilos.}$$

Since, in point of fact, 3·75 kilos. of butter were obtained from 100 kilos. of milk with 3·45 percentage of fat, the success of the yield is thoroughly satisfactory. By means of the formula given, one can calculate, therefore, provided the average percentage of fat in the milk, which has been churned, and the yield of butter per 100 kilos. of milk is known, whether the yield comes up to the required standard or not.

77. The Forces which are brought into Operation in the Action of Separators.—In dairies in which 1000 kilos. of milk and more have to be treated daily, separators are worked only by steam. It may be generally affirmed that the application of steam pays, if, on an average, 300 kilos. of milk are daily treated. If a smaller quantity of milk has to be treated, hand-separators may be used, if it be not possible to form a branch of a co-operative dairy company. In smaller separating dairies, that is, in those in which 300 to 1000 kilos. of milk are creamed, it is doubtful whether steam or winch or the application of some minor motor—petroleum or hot-air machine —is best. There are cases in which the winch is very suitable. On the whole, however, steam is cheaper, which can be easily demonstrated if the expenses are exactly estimated, and if it be taken into account that in the case of the winch the cost of an attendant and one or two horses is incurred. Even the best winches do not yield their impelling power as regularly as is required for the driving of separators. Steam-engines are most suitable for dairies in which separators are worked by power, for the reason that both motor power and heat are already there

for use. Small motors, such as winches, only supply power, and work scarcely cheaper than steam-engines. The conveniences and advantages of their use do not more than counterbalance their limited utility. They are, therefore, not to be recommended for use in dairies.

78. **Hand-separators.** — Although hand-separators are admirably adapted for use on a small scale, they are, on the whole, of little importance for extended application. The best course to pursue in the case of dairying on a small scale, in order to secure the largest price for milk, to enjoy the advantages of wholesale trade and capital, and to save time and labour, is the co-operative treatment of milk supplied by many small cow-keepers, and *carried on in one place under competent direction.* It is on this account that the extended use of hand-separators, even in districts in which there are excellent small independent farms, is only economically justifiable so long as the erection of co-operative dairies, for various reasons, is not advisable. Under certain circumstances, they offer great advantages in small agricultural districts in the neighbourhood of towns, and in small milk businesses carried on in towns. In country agricultural districts they are employed generally twice daily, viz. during milking. It is hardly necessary to say that the separation should not be carried on in the byre, but should be done in a clean room reserved for the purpose, and supplied with pure air. The more carefully all precautions which are advisable in the case of large separators are carried out, the better will the return be for the large capital invested in them. It is especially necessary in their case to maintain the prescribed rapidity of the drum.

79. **The Separator Residue.**—On the inside of the separators, especially on the sides of the drums, there is always found, after they have been in use, a dirty, slimy, highly-distasteful viscous mass, the so-called separator residue or mud, which can often be taken off as a skin in large pieces. It is quite erroneous to suppose that this mass consists simply of the impurities present in the milk. No doubt it contains all the solid impurities which have come into the milk, small quantities of food, pieces of dung, hair, bristles, inorganic mud, and many bacteria and other microscopic organisms. It is, however, chiefly composed of the constituents of the milk, especially the caseous matter, which forms about nine-tenths of the weight of its dry residue. According to the season of the year, the weight of

the residue forms ·05 to ·13 per cent of the weight of the separated milk. The loss of nitrogenous matter which the milk suffers in the process of separation is inconsiderable, as it only consists of from ·5 to ·8 per cent of its entire amount. This loss is of such a kind, however, that the formula devised by the author for the calculation of the dry substance of milk from its specific gravity and its percentage of fat is not applicable to skim-milk obtained from the separator.

Investigations, carried out at different times at Raden, showed that the fresh separator residues had, on an average, the following composition:—

Water, ...	67·3
Fat, ...	1·1
Caseous matter, ...	25·9
Other organic constituents, ...	2·1
Ash, ...	3·6
	100·00

Two analyses made at different times showed the composition of the ash of the separator residue to be, on an average, as follows:—

Potash, ...	3·155
Soda, ...	1·325
Lime, ...	45·025
Magnesia, ...	3·361
Sesquioxide of iron, ...	1·848
Phosphoric anhydride, ...	43·976
Chlorine, ...	1·691
	100·381
Deduct oxygen replaced by chlorine, ...	·381
	100·000

80. Cream.—If the numbers indicating the weight of the cream and the skim-milk, after the separation of the milk, be added together, it will be found that the sum of the two is never equal to the number representing the weight of the milk, since losses occur through the evaporation of water, the clinging of water to the sides of the vessels, and unavoidably in the pouring of the milk from one vessel to another. Where separation is carried on carefully, these losses in large separating dairies should not exceed ·5 to ·75 per cent of the weight of the milk. Investigations carried out on the older creaming methods, on cream and skim-milk, showed that if water were allowed to evaporate from the milk during creaming, a distinct increase in the proportion of protein occurred, with a diminution

in the ratio of the milk-sugar to protein, and that the skim-milk experienced a slight increase in milk-sugar.

The cream obtained in German dairies in which separators are employed contains, on an average, between 14 and 20 per cent of fat. Should it be desired, cream containing a larger proportion of fat can be obtained from separators. It resembles butter, and contains more than 60 per cent of fat. Comparatively thin cream, containing 8 to 15 per cent of fat, is commonly known as coffee cream, and the thicker cream, containing more than 15 per cent, is known as whisking cream. In other countries than Germany, for example, in England, the public requires a cream rich in fat.

The great bulk of cream obtained in dairies is utilized for the manufacture of butter. No doubt cream is used generally as an article of luxury, and forms, especially in town, a much-prized and, therefore, very lucrative article of commerce. The different names used for cream are Sahne and Schmand (in East Prussia and the Eastern Sea provinces), Kern, Flott (in Middle Germany), Schmetten, Obers (in Austria), Nidl (in Switzerland).

Cream chiefly contains the largest of the fatty globules of milk. The following figures show the chemical composition of cream, and illustrate its variation in fat:—

Water, ...	76·6	71·7	66·3	29·0
Fat, ...	15·2	20·0	25·0	67·5
Nitrogenous matter,	3·1	3·1	3·2	1·2
Milk-sugar, ...	4·5	4·6	4·8	2·2
Ash, ...	0·6	0·6	0·7	0·1
	100·0	100·0	100·0	100·0
Sp. gr. at 15° C., ...	1·017	1·014	1·011	0·947

The following is the composition of the ash of a sample of cream containing 15·2 per cent of fat:—

Potassium oxide, ...	28·381
Sodium oxide, ...	8·679
Calcium oxide, ...	23·411
Magnesium oxide, ...	3·340
Iron oxide, ...	2·915
Phosphoric anhydride, ...	21·735
Chlorine, ...	14·895
	103·356
Deduct oxygen replaced by chlorine, ...	3·356
	100·000

The quantity of phosphoric acid quoted includes that which has been formed by the burning of the protein bodies containing phosphorus.

The percentage composition of fat (x) of the cream may be found by the following formula, in which (f) denotes the *percentage of fat in the* milk, (f_1) the percentage of fat in the skim-milk obtained, and R the weight of cream expressed in percentage of the weight of milk, by the *formula given in* § 74, viz. $x=\frac{100\,(f-f_1)}{R}+f_1$, and the percentages of the quantity of cream R, which must be removed from the milk if the *percentage of fat of the cream is to be obtained as* x *per cent*, is as follows:—

$$R=\frac{100\,(f-f_1)}{x-f_1}.$$

The money value *which the* cream possesses *for the* producer can be easily ascertained. For example: If from 100 kilos. of milk there are obtained 3·75 kilos. of butter, valued at 2 marks, and the butter-milk is valued at ·02 marks; and it be estimated that 100 kilos. of milk yield 20 kilos. of cream, the following shows the method of calculation:—

3·75 kilos. of butter at 2 marks,	... ...	7·5 marks.
16·00 kilos. of butter-milk at ·02 marks,	...	·32 „
0·25 „ loss.		
20 kilos of cream are worth	... ...	7·82 „

According to this calculation, 1 kilo. of cream is worth 39·1 pfennig. In order to calculate the net value, however, the expenses due to the preparation of the butter, and the value of the butter-milk, must be deducted. The market price, as a rule, considerably exceeds the true value of cream. Cream with 14–20 per cent of fat may, on an average, be valued at four times the same quantity of milk.

81. Skim-milk.—Skim-milk is a by-product of the dairy industry, and the small quantity of fat it contains is chiefly in the form of the smallest fat globules of the milk. In addition to the common constituents of milk, it generally contains small quantities of free lactic acid. Compared with milk, its composition is more watery, and its colour appears at average and higher temperatures slightly bluish. Skim-milk obtained in well-conducted dairies has a specific gravity, which at 15° C. varies between 1·032 and 1·0365,—on an average, 1·0345,—and contains, according to older methods of cream-raising, ·8 per cent of fat, and when obtained in separators not more than ·3 per cent. It is used for the preparation of skim-milk cheeses for

human food, and as a feeding material for swine and calves. This will be dealt with further on. For general purposes, with the exception of the manufacture of sour-milk cheese, the less free lactic acid the skim-milk contains the better it is. Skim-milk is, in the true sense of the word, a food, and belongs to the most valuable class of foods. It is obvious, of course, that its nourishing value is narrower than that of milk, and that it is a one-sided food. For this reason it is not suited for the nourishment of children during their early life. Its value consists solely in the percentage of proteids, milk-sugar, and mineral salts it contains. The small quantities of fat which are present are hardly worth taking into account. The skim-milk obtained by separators is more valuable than that obtained in the older processes, since it is characterized by greater cleanliness and freshness.

In feeding pigs with skim-milk, according to the price of meat, which ranges between 60 and 80 marks per 100 kilos. of live weight, experience has shown that the kilo. of skim-milk may be taken to have an average value throughout the year of about 3 pfennig. If in different places its value is higher, it will be well not to rely on speculative calculations, but to stick to the above price.

The fresher the skim-milk is which is used as calves' food, and the more fat it contains, the more nutritive will it be. With regard to the value of skim-milk in this connection, average figures are not of much general use. This is owing to the fact that it is strongly influenced, not merely by the breed and treatment of the calf, by the duration of the feeding, the condition of the market, and the degree of care which has been bestowed on the young animal, but also on a condition, which it is not easy to take into account, but which has a great influence, viz. the fortune and the individual good luck of the management in the treatment of the calves. In the production of a kilo. of live weight the few experiments which we have on the subject show that where skim-milk is used as the sole food for calves, and where the feeding period lasts from 10 to 12 weeks, somewhere about 18 to 20 kilos. is necessary, that is, somewhere about twice as much as would be required of whole-milk for the same purpose. It has been often tried, by suitable additions, to increase the nutritive value of the skim-milk, which has the very narrow average nutritive ratio of 1 to 1·5. Good results have followed the addition of linseed-oil to skim-milk in order to enrich it in fat for feeding calves. Emulsions of fat in skim-milk, which

will keep for some time, may be easily prepared with the separator. In feeding pigs it is possible to increase the nutritive value of skim-milk by feeding with potatoes at the same time.

Under favourable circumstances, a kilo. of fresh skim-milk, as a food for calves, may have a value of 3 pfennig. The utilization of skim-milk as a food for other domestic animals, besides calves and pigs, is very limited, and we need not deal with it here.

Skim-milk possesses, on an average, the following composition:—

	Old method.		Separator.
Water, ...	89·85	......	90·30
Fat, ...	0·75	......	0·25
Protein matter, ...	4·03	......	4·00
Milk-sugar, ...	4·60	......	4·70
Mineral matter, ...	0·77	......	0·75
	100·00		100·00
Sp. gr. at 15° C.,	1·034		1·035

The analysis of the ash of a sample of skim-milk, obtained by the separator, is as follows:—

Potassium oxide, ...	31·634
Sodium oxide, ...	10·265
Calcium oxide, ...	21·913
Magnesium oxide, ...	3·115
Iron oxide, ...	0·921
Phosphoric anhydride,...	19·478
Carbonic anhydride, ...	1·000
Chlorine, ...	15·071
	103·397
Deduct oxygen replaced by chlorine, ...	3·397
	100·000

The 19·478 per cent of phosphoric acid includes that formed in the burning of the proteids containing phosphorus, and the sulphuric acid arises entirely from the sulphur of the proteid substances.

The value which a kilo. of skim-milk possesses in any district is very easily determined. If it be known that 100 kilos. of milk, for example, yield, on an average 3·5 kilos. of butter at 2 marks, and 16 kilos. of butter-milk at ·02 of a mark, the value of the cream will be 7·32 marks. If the value of 100 kilos. of milk be assumed to be 12 marks, and if 78 kilos. of skim-milk be obtained from this quantity of milk, the value of a

kilo. of skim-milk will be $\frac{468}{78} = 6$ pfennig. A kilo. of skim-milk could be sold at 6 pfennig, which would cover the expense which had, up to that time, been incurred in the production of the skim-milk in the dairy.

In towns, skim-milk possesses a value which is practically half that of the same volume of whole-milk. A kilo. of lean ox-flesh contains 18 per cent of protein and 5 per cent of fat, that is, in 100 kilos. there are 23 kilos. of valuable constituents. If the nutritive value of protein and fat are reckoned as equal, and if no account be taken of the value of the remaining constituents of the meat, and that the cost of 100 kilos. of ox-flesh is 100 marks, therefore the price of a kilo. of protein or fat equals $\frac{100}{23} = 4 \cdot 35$ marks.

If 100 kilos. of skim-milk contain 4 kilos. of protein and 4·5 kilos. of milk-sugar, and this latter only worth a fifth part of a kilo. of protein, there is in the skim-milk altogether 4·9 kilos. of constituents of the value of the protein. Leaving out of consideration, as of no value, the fat contained in the skim-milk, if 100 kilos. of skim-milk cost seven marks, the value of a kilo. of protein is $\frac{7}{4 \cdot 9} = 1 \cdot 43$ marks. From this it will be seen that a kilo. of protein in lean ox-meat is three times dearer than in the skim-milk. Skim-milk, therefore, cannot be too strongly recommended as one of the cheapest and most serviceable of foods.

82. **General Remarks on Butter-making.**—Butter consists, as has already been pointed out in § 4, practically of the fat which is originally present in the milk in the form of countless extraordinarily small globules. The collecting and uniting together of the largest possible amount of these fatty globules is effected most thoroughly by shaking and beating the fluid which contains the fatty globules—that is, churning—for a time, in vessels specially constructed for this purpose, viz. butter-churns. The butter may be directly obtained from the milk as milk butter. By far the greatest part of the butter, however, which is in daily use, is cream butter. We have already seen in § 6 that all, or at any rate the larger number of the fatty globules, present in milk or cream at ordinary temperatures, are in the fluid condition. Since butter is separated out as a solid body, it follows that the milk-fat is converted from the fluid to the solid condition by the shaking which it undergoes while churning. We further know that the fatty globules are surrounded with milk-serum, and that, owing to the molecular strain caused in this way on their surface, they are very difficult to bring into direct contact with each other. Since it has been found from experience that milk and cream, as soon as souring has taken

place in them, are, to a certain extent, much more easily and perfectly churned than when in a sweet condition, it must be concluded that the forces which effect the union of the fatty globules increase with the greater souring of the milk. When it is considered, however, that in souring, the condition of the different phosphates which are present in milk is changed, and in consequence of this the original chemical condition of the caseous matter, and the nature of its source, is also changed, it would appear as if churning in every respect succeeded best after the original condition of the caseous matter had suffered, up to a certain degree, a change in its state of tenuity. To effect this condition of the caseous matter is the chief object of the process of souring, by which cream and milk are prepared for churning. It has hitherto been impossible in churning sweet milk to obtain even comparatively satisfactory results, and it is for this reason that in treating milk for butter the milk is nearly always treated in the sour condition. Sweet cream, if properly treated, yields a satisfactory quantity of butter, although less than sour cream. In practice the churning of sweet cream is only carried out on a very limited scale. By far the largest proportion of butter is made from sour cream.

In churning, butter separates out in round greasy granules, which on an average are 2 millimetres in diameter, that is to say, about the size of the head of an ordinary pin. They float about in the butter-milk, which is a bye-product of the churning. The little masses which are formed by the union of the small granules may be called raw butter, in distinction to the finished article, which is formed by kneading and working up the raw butter. The weight of raw butter and of butter-milk obtained together never represent the whole weight of the milk or cream treated, but are always ·5 to 1 per cent less. It is not possible to make into butter all the fat present in the milk or cream, a small residue, amounting to 2 to 4 per cent of the entire mass of the fat originally present, remaining behind in the butter-milk, according as to whether milk or cream has been treated. The manufacture of butter from sour milk, sour and sweet cream, will be discussed later on.

83. **Butter Churns.**—The first condition of every butter churn is that, under proper treatment, thorough separation of raw butter from the milk or cream should be effected without difficulty, in from 35 to 45 minutes. The more simple and perfect the arrangement of the churn is for effecting this, the better the churn is. Experience

with an endless number of artificial and complicated arrangements which have been tried in butter churns in the course of time, and of numberless different methods which have been proposed for putting the churn in motion, has demonstrated that, the simpler the construction of the churn, the better it is. The following few conditions must, however, under all circumstances, be fulfilled:—

(1) The opening for pouring in the milk or cream and for taking out the raw butter should be as large as possible, so that the churn may be conveniently cleaned, sufficiently aired, and thoroughly dried. It is also important that no portion of the inside of the churn be out of reach of the hand, so that it can be completely cleaned.

(2) The churn must have a simple and sufficient lid to prevent loss of milk while churning is proceeding.

(3) The churn should be light, convenient, and durable.

It is desirable that a thermometer should be placed in the inside of the churn, which would indicate the temperature obtaining during churning.

The best material for butter churns is good wood, free from faults, of a firm texture (beech, oak, or pine). Churns made of iron, whether painted or enamelled, are not suitable, and churns made of white metal, with water-baths, offer no special advantage. Every new churn must be prepared for use by thorough repeated washing with hot and cold water. After it has been used it should be at once emptied, cleaned, and set up to get aired and dried.

Nothing is easier than to make churns which will yield butter in five or ten minutes' time. Such churns are, however, quite useless, since they neither yield a satisfactory quantity of butter nor a butter of good quality.

According to the size of the churn, it is either worked by hand or by machine. In churns worked by machinery, animal power and water power are sometimes used, but more generally steam power.

Churns may be divided into (1) churns with beating action; (2) swinging, cradle, and rocking churns; (3) horizontal churns, with dash; (4) vertical churns, with dash; (5) and churns with special arrangements for stirring the fluid. These chief groups may be subdivided into other smaller ones, which depend on slight differences in their arrangement, and are very numerous.

84. Churns.—The churns with beating action have a stationary barrel, and either one or two beaters. In the churns with one

beater the barrel makes a pendulum-like motion during churning. The most of them are made out of wood. Some of them, however, are made out of white-metal and other materials. Nearly all the improvements introduced in this type of churn consist of lightening the motion of the butt. They are suited for hand use for small districts in which butter is not made daily, and where it is of little consequence whether churning requires little or much labour. Formerly they were extensively used. At one time they were used even where butter was made on a large scale, and were set in motion by winches, and in America even by power.

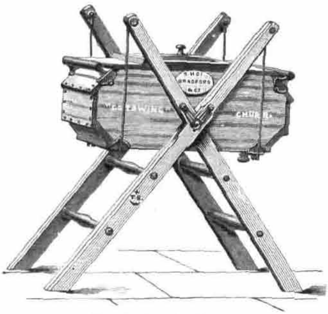


Fig. 47.—Cotswing Churn.

If we except the fact that the movement of the beaters is tiring, they discharge their duties very satisfactorily. It is highly probable that the beating churns are the oldest churns. They can be filled half full, and the beater, according to the size of the barrel, is made to give 50 to 100 beats in a minute. It is not necessary to use a thermometer in the churn.

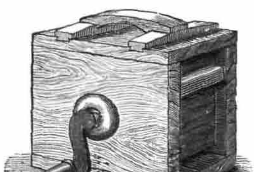


Fig. 48.—Box Churn.

Some twenty different kinds of these beating churns are known to the author, among which the simplest in use in Germany, Holland, and America are the churns of Ryerson, Westman, Lindsay, Gussander, Clifton (air churn), Pieper, Menken, Holmgren, Bailey, Cater, Sayer, Drummond, Renne's Lewi (with a pendulum barrel), Wilson, Zackel, Achenbach, Savary, Ed. Stevens (standard churn), A. Bedros, &c. (figs. 47 and 48). The best beating churn is the old wooden beating churn of simple structure.

85. Swinging, Cradle, and Rocking Churns.—In all these churns

the barrel moves, and rolls around an axle, or rocks, or makes both these kinds of motion at once. They are generally made of wood, occasionally of white-metal. Those that are in by far the most extensive use are the swinging churns. The cradle churns, which were formerly much used, are now almost entirely given up, and the swinging churns are only found in small English and American dairies. The nature of these churns necessitates the stopping of the churning from time to time to permit of the air in the barrel becoming discharged. For this reason, the opening in the barrel is smaller than is desirable in the interests of cleanliness and airing, and the extent of their motion must not be allowed to exceed a certain limit. It is not easy to introduce the thermometer into the barrel. These disadvantages, however, are more than compensated for by the fact that it is of all kinds of churns the most easily set in motion and maintained in motion, a point of enormous importance in churns for hand use. In the case of good swinging churns, the opening in the cask is wide, the taps of the bowls rest on anti-friction-rollers, and the dashers, when such are present, are so arranged that they can be easily taken out. Churns of this kind made after the simplest pattern, as, for instance, the Lefeldt or Victoria churns, are the best churns for hand use. The swinging churns do not suit the conditions of large dairying. They cannot be filled quite half-full, and require, according to their size, 30 to 100 revolutions per minute.

Fig. 49.—Diaphragm Churn.

There are a large number of different swinging churns. They are as follows:—

(1) Those of common construction, in which the barrel is allowed to revolve round a centre axle; (*a*) those with a wooden barrel, the churns

of Muhlstein form, those of Normandy, Lefeldt, J. J. Schmidt, Olivier, Fouju, Faccioli, Linkler, Eastwood, Bamber, Hathaway, Bradford (fig. 49), Atkinson, W. Hopperton, W. Waide; (*b*) those with barrels made of white-metal, the churns of Rangod, W. Alway & Sons, and Harrison.

(2) Wooden churns which are moved end over end, that of Burchard, Victoria churn (fig. 50), and Ahlborn's Triumph churn.

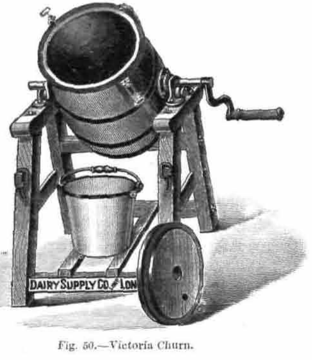


Fig. 50.—Victoria Churn.

(3) Butter churns which are moved by an axle going right through the cask. The churns of Tyndall, Midelot, Thomas & Taylor, and Julius Hummel. To this variety belong the American box churn.

Among the cradle and rocking churns may be mentioned the rocking churn of Wales, the French rocking churn, and the churns of Weisze, Eberding, C. Seeger, H. Knappe, Bullard, Davies, Hathaway, Valentine, Landsberg, and A. Geiger (made of glass, for use on the breakfast table), &c.

86. Churns with Horizontal Barrels.—Although churns of this kind exhibit great adaptability of structure, they are comparatively little used. They are only suitable for hand use, or for use on a small scale, from the fact that when in use they cannot be half-filled. They are unsuitable for use on a large scale, or for churning large quantities of milk, an objection which appertains to all dash churns with horizontal barrels, and consists in the fact that the liquid to be churned is easily polluted on its way from the bowl to the edge of the barrel. It is not easy to introduce a thermometer into the barrel. On the other hand, there is no objection to making the opening of the cask very large, and thereby materially helping the cleansing and airing process. In the case of wood churns of this kind, the opening of the cask should be wide, the wall through which the bowl goes sufficiently strong, and the paddles so constructed that they may be taken out. In churning, the barrel makes

75 to 120 revolutions in a minute, and, if a toothed-wheel arrangement be employed, even several hundred revolutions in a minute can be made. Among good solid hand churns with horizontal barrel may be mentioned those of Blanchard, Petersen, and Hausen and Spain.

87. **Churns with Vertical Barrel.**—The dash churns with upright barrel, of simple construction, are the most admirable of churns for use on a large scale. If the barrel be conical in shape, it may be filled to almost two-thirds of the contents of its internal space, so that these churns are, relatively speaking, the least heavy and unhandy to work when churning large quantities of fluids. They are not adapted for hand use, since, in the transmission of movement by the handle to the barrel, conical-toothed wheels or other force-destroying apparatus must be used. They are therefore very heavy to work with the hand. Good dash churns with upright barrel are constructed in such a way that the dasher may be taken out. The barrel is provided with a simple pinion arrangement, above which is a cup for holding oil. The barrel receives 90 to 150 revolutions per minute, according to whether it is milk or sour cream that is being churned. Churns of this kind, the barrels of which revolve more quickly, do not last long. Some thirty of these dash-churns are known to the author.

88. **Churns of Uncommon and Special Construction.**—Churns of this kind have unfortunately no value. The experience of centuries has shown that good butter can only be obtained in the largest possible amount when separation of the butter from the properly prepared fluid does not take place too quickly—that is, in somewhere from 30 to 45 minutes,—and this object can be easily obtained by the simplest kind of movement of the liquid. It is an idle attempt to try and effect an advance in the preparation of butter by introducing any new kind of motion of the liquid, or by the introduction of artificial arrangements in the churns, a fact which ought to be once and for all clearly stated. An example is the lately-exploded idea that an improvement can be effected by causing movement by the suction of air into the liquid, as is the case in the churn of Rolland, Francois, & Co.

In conclusion, the following churns may be mentioned, which are known to the author simply by name:—Weston, Whitelaw, Duchene, Ransome, Hancock, Pearce, Dashorst, Zimmermann, Klaaszen, Loon,

Bowler, Fischer, Samson, Seignette, Qudaille, Derlon, Charles, Maugrain, Penn Hélouin, Montslet, Touzet, F. Denis, Destrag, and Turchini.

89. The Practical Value of the Different Churns.—In connection with this subject a number of opinions have already been expressed in the foregoing paragraphs, from which it may be inferred that there is no one absolutely perfect churn—no one churn which, under all conditions, is equally well suited for butter-making on a large and on a small scale. For manufacture on a small scale the simple wooden churn is the best, perhaps a simple wooden churn with a horizontal barrel. The best churn for manufacture on a large scale is the so-called improved wooden Holstein churn with upright barrel.

90. The Preparation of the Milk for Churning.—If the liquid is to be churned in a sweet and unsoured state, which may be the case with cream, but not with milk, it does not require any preparation. In the case of churning a sour liquid, the preparation for churning has as its aim to induce and develop lactic fermentation, in the perfectly fresh substance, in such a way that the original condition of the caseous matter, and with it the condition of the fluid, should become such, within 18 to 24 hours, as to be capable of yielding the best and the largest possible quantity of butter in a good condition and of uniform quality. In practice, cream is often, and milk is always, *left to become sour of their own accord, and in that way the yield* of butter is left to chance. Such treatment is to be condemned as thoroughly uneconomical. When the fluid has obtained the condition which experience has shown to be most favourable to churning, it is known as ripe for churning. Ripe milk should be uniformly gelatinous (thick as the liver, as the farmers say), and ripe cream should be uniformly leathery. For the purpose of judging of ripeness there are no indications or infallible tests. It is only to be known by practice and experience. If the liquid has not quite gained a sufficient degree of ripeness before churning, the result is that less butter is obtained, and if the degree of ripeness be exceeded, the nature and keeping quality of the butter suffer. To obtain ripeness in a longer or shorter period than from 18 to 24 hours has been shown to be risky, since under such conditions uniform ripeness can scarcely be expected to take place throughout the entire mass of the liquid. In the case of ripeness obtained in a shorter period, it is scarcely possible to note daily the most suitable time for churning, as the condition of the fluid changes so quickly;

and in the case of ripening more slowly, the cream or the milk is exposed longer to all possible accidental sources of injury than is desirable in the interests of the keeping quality of the butter.

In order to effect ripening in from 18 to 24 hours, the liquid should be placed in large vessels of wood or of white-metal, in a warm and easily ventilated room with a northern exposure. The lactic ferment should be added in sufficient quantity to produce the necessary sourness. The milk should be gently stirred from time to time with a suitable stick made of good wood, and the vessel may either be slightly covered or be open as desired. The milk is to be maintained at as uniform a temperature as possible, which may vary between 15° and 20° C.

Formerly butter-milk from the previous churning was almost universally used as a sourer. This is still often done, and such a method is all right, provided the butter-milk contains fairly pure lactic ferment, which is capable of producing a rapid development of lactic acid. As soon, however, as other ferments crowd out the lactic ferment in the butter-milk, a state of matters which may easily occur in summer, the milk may become seriously affected. The cream may become caseous or the butter may become oily, a state of matters which may last for months, since the sourer is always obtained from the butter-milk of the previous churning. This may be avoided if, as is now generally done in all well-conducted dairies, the sourer be prepared fresh every day. This may be effected in the following way:—

A small quantity of milk or skim-milk is allowed to sour. This should not be more in amount than 6 per cent of the total quantity to be subsequently soured. After lactic fermentation has become well developed in this portion, it is used as a sourer. For this purpose small metal bowls are used, similar to the Swartz bowl. They are covered with felt, placed in a wooden box in clean dry straw, and after they have been filled they are covered with a close cloth. In the bowls the milk or skim-milk, which, according to circumstances, has been heated to a temperature of from 20° to 30° C., before being poured out, is allowed to stand for 24 hours in some place with a pure atmosphere. Sweet skim-milk, obtained by the Swartz or separator method, is more suitable than milk, because no cream is formed upon it, and there is no fear, therefore, that the susceptible milk-fat on the surface of the liquid will become tainted during souring, and impart a bad flavour to the liquid to be soured. Since skim-milk sours more slowly than whole-milk, on the surface of which a dense layer of cream quickly forms, the sourer is generally produced from whole-milk. In this case no time should be lost in tasting

the cream formed during souring before using it, and discarding it if it possess the slightest flavour. The quantity of sourer used should not exceed at the most 5 per cent of the liquid to be soured. It is better to use only 2 per cent, or even less, for cream, as it is only with cream it is used, since milk which is to be churned is allowed to sour itself, and the temperature of the cream should be raised somewhat during souring, within the limits already mentioned. These limits, which are 16° to 20° C., must be rigorously maintained, since experience has shown that the security of the manufacture is endangered if these limits be exceeded, either above or below. There is no necessity to exceed these limits, since the margin which they give, though apparently a narrow one, is sufficient at every season of the year to regulate the temperature of the cream so that it may safely ripen in from 18 to 24 hours. Ripening is either hastened or retarded by bringing the temperature of the cream for a shorter or longer period nearer to the higher or lower limit. By a diligent and regular observation of the temperature of the souring of cream, by frequently tasting it, and, above all, by carefully watching the progress of the souring, an amount of knowledge and experience can be readily gained by means of which successful work is secured much more surely than by repeated and exact determination (chemical) of the lactic acid in cream. By too little souring the yield suffers in quantity, but only to a slight extent, while the quality is not at all impaired. On the other hand, in the case of too much souring, a yield of good butter is impossible. Especial care should be taken, therefore, that the cream is not allowed to become too ripe—that is, too sour.

There are no practical experiments to show whether the cream-souring effected by lactic fermentation can be replaced by artificial souring by means of lactic or acetic acid. It is also very difficult by the latter means to effect in an equable and perfect manner the ripening of the fluid to be churned. That is best effected by lactic fermentation taking place equally throughout the whole mass. If the butter possessed any blemish which can be traced to the disturbed development of the souring of the cream, pure cultures of lactic ferments should be at once obtained for souring the Pasteurized cream, and such pure cultures should be used until it is possible to again obtain a good sourer, by allowing the milk to become spontaneously sour. Such pure cultures of lactic ferment can now be easily obtained at the dairy experiment stations. By regularly Pasteurizing the cream, the yield of a uniformly good butter is greatly promoted.

91. Churning.—The changes which take place in the churn during churning, from the solidifying of the fat of the individual fatty globules of the milk, to the appearance of the little lumps of

butter about the size of pin-heads, and the individual circumstances which influence the firmness and percentage of water in the texture of the raw butter, are theoretically little understood. Up till now, on this account, the rules for churning have been exclusively drawn from practical experience alone.

Butter of the best quality, and possessing the best keeping properties, contains, as experience has shown, not more than 15 per cent of water. It is neither soft nor oily, nor on the other hand hard or friable, but possesses an average degree of softness and a characteristic texture of grain, by which its origin from countless quantities of individual globules and small lumps of hard fat can be easily recognized under the microscope. Butter of this uniform quality can only be obtained when churning is carried on neither too long nor too short a time, and neither too slowly nor too quickly. The best results are obtained when churning lasts for from thirty to forty-five minutes, a period which is only limited by the exact violence of the movement and the exact temperature of the liquid which is being churned. Within certain narrow limits the violence of the motion is in inverse proportion to the height of the temperature, so that with a more or less powerful movement the same effect can be produced as can be effected by a corresponding increase or decrease of temperature. The art of making good butter from good ripe milk or good ripe cream consists solely, for the above reasons, in so regulating the temperature of the liquid for each individual churn, and for the churns of different kinds, that the production of the raw butter is effected in the prescribed time. Butter receives its texture and its consistence in the churn during churning, and defects which are produced during churning can be by no means subsequently removed.

The obstacles which retard the union or the coalescence of the butter globules to form the lumps of fat are decreased with an increase in the temperature of the fluid; and the more violent the motion, even to such a degree that heat is produced, the more easily are they overcome. It may be pointed out that where churning takes place too quickly, either through too high a temperature or too violent a movement of the fluid, the little lumps of raw butter do not separate out easily, but include, besides the solidified fat, fatty globules which are in the liquid condition. The author is further of opinion that the little lumps of fat take up more butter-milk, in the form of small microscopic drops, the more quickly they are formed. If the little lumps of butter contain liquid fat

which is only solidified by the subsequent treatment of the raw butter, and which becomes smeared between the previously solidified fat, the granulation of the texture is partly injured, and the finished butter must show a soft smeary condition. In a similar manner butter which has taken up too much liquid in the churning will be soft, and will contain an unusually high percentage of water, since, even after long-continued treatment, only a small quantity of this water can be driven out, because it is present in the butter in such a fine state of division.

If churning does not take place satisfactorily within the prescribed time, it is an indication that the temperature is not sufficiently high, or that the motion is not sufficiently violent. If the temperature is found to be higher at the conclusion of the churning, it cannot be expected that the little lumps of the raw butter will be of uniform nature. It is more probable that in such a case, owing to the weak motion in churning, they will include much liquid fat, and that owing to the final quick churning they will contain unusually large quantities of butter-milk. Experience shows that oily butter is obtained by too quick, as well as by too slow churning. Not only, however, does the quality of the butter suffer in such a case; but the yield of butter is also diminished. The motion of the liquid in the churn is always closely connected with the development of temperature. The quicker the motion, the more does the temperature, which the liquid originally had, rise, a fact which has to be reckoned with in churning. The rise of temperature in churning sour milk or cream should not exceed 1° to 2·5° C. In the properly-conducted churning of sweet cream an increase in temperature of 3° C. or even more has been observed.

As a result of experience, the following points are worthy of attention:—

In the first place, the ripe milk or cream is weighed and brought up exactly to the temperature which, from experience, it is known will effect churning in from thirty to forty-five minutes. This temperature is not the same for similar fluids in each place and for each kind of churn, or even in the same place and for the same churns throughout the year, but varies according to different conditions. The size, the special arrangement of the churn, especially the speed with which the fluid is churned, the quantity of the fluid in proportion to the cubic contents of the churn, and the season of the year, will all influence it. The imparting to the fluid of the proper temperature is best effected by pouring it either partly or entirely into a metal vessel, and keeping it there in water of 30°, or at most, 35° C., as long as is necessary. Small differences in temperature can be most effectively equalized by the so-called cream boxes, which are filled with warm or cold water. These boxes, filled with ice, are excellently suited in summer for cooling a liquid to be churned. After the fluid, warmed to a proper degree, has been poured into the churn, its temperature is again

taken, in order that the fall in temperature due to the changing from vessel to vessel may be counteracted. Churning is then started. During churning nothing must be done to regulate the temperature. The temperature of the fluid should be observed, however, and also the first appearance and the gradual development of the lumps of butter. As soon as the lumps have assumed the proper size, churning is at once stopped. The lumps of butter are then washed from the paddles and the sides of the churn, with pure, previously boiled and sufficiently cooled water, or with skim-milk, for which purpose a small pouring watering-can with a rose should be employed. The butter is then taken out of the churn with a hair-sieve, and is freed from the greater portion of the butter-milk which remains clinging to its surface, by dipping it while in the sieve several times into pure cold, previously boiled water. The remainder of the fluid, which adheres to the surface of the butter, is removed as thoroughly as possible in the subsequent treatment of the raw butter. Finally the mass of butter obtained has to be weighed, and it has to be calculated how many kilos. of milk have been required to produce a kilo. of butter, or how many kilos. of butter have been obtained for every 100 kilos. of milk. If the butter be salted, it is generally weighed in a fresh condition, before salting, in order to determine how much salt it will be necessary to rub in. The temperature at which churning begins is as follows:—

For sweet cream, ...	11·25° to 15° C.,	on an average	13·125° C.
For sour cream, ...	12·50° to 20° C.,	do.	16° C.
For sour milk, ...	15° to 21·25° C.,	do.	18·125° C.

In the most successful experiments, it has been found that in the case of sweet milk subjected to unusually violent churning, the process of churning should begin at 7·5° to 8·75°, on an average 8·125° C. Milk or cream from the milk of milking-cows long calved, since it is more difficult to churn than the milk or cream of milking-cows recently calved, must be set for churning at a higher temperature. The author has found that cream from milk of milking-cows long calved must first be brought to 24° C. before it can be churned. As is to be expected, the yield in respect of quantity and condition of butter is not very satisfactory.

If, owing to any oversight, the proper temperature for churning a liquid has not been chosen, the error may be rectified in exceptional cases by adding warm or cold boiled water. In the application of such a remedy, which is always hazardous, it is especially important to see that only absolutely pure water, heated at the most to 40° C., is used.

No substances can be added to the liquid to be churned which facilitate churning or improve the butter. The so-called butter powder, which is

often advertised, contains, as its chief constituent, sodium carbonate, and perhaps also alum or salt or saltpetre or annatto, and consequently can only act as a neutralizer of the acid, or impart to the butter a higher colour. Among the harmful substances added occasionally, with malevolent intent, to a liquid to be churned, are soap-lye, sal ammoniac, even small quantities of which retard or render churning quite impossible. Sugar-gum, lime, spirits, meal, crumbled bread, to which a harmful action has been also ascribed, have no bad effect if added in small quantities.

If in winter the room in which churning is to be carried on is not warm, or in summer is not cool enough, the churn should be cooled or heated, before churning, with hot or cold boiled water.

If the butter has to be coloured, the butter colour should be measured in proper proportion, and cautiously mixed with the fluid in the churn immediately before churning is commenced, so that none of the colour may come into contact with the wood of the churn and thus be lost.

A daily register of the initial and final temperature of the liquid and the length of time of churning ought to be kept, and this register ought to furnish a useful table of reference for judging of the speed of motion.

So far as the author is aware, it has not been attempted to churn daily and regularly in one churn more than 400 kilos. of liquid.

92. **Churning of Sour Cream.**—Sour cream is comparatively more easily churned, and yields, when the souring has been properly done, a butter which possesses the best keeping properties. The temperature at which churning begins varies, under ordinary conditions, between 13·75° and 17·50° C. In large dairies the Holstein churn of improved construction is almost exclusively used, and the churn is worked at the rate of from 110 to 120 revolutions per minute. The quantity of cream which is churned in this churn must be at least large enough to stand 10 centimetres above the lower cross-piece of the fly-wheel of the churn, and must not be, on the other hand, so large that it stands more than a similar height above that point. During churning, which should be completed in from 30 to at the most 45 minutes, the temperature of the cream ought not to be allowed to rise higher than from 1° to at most 2·5° C.

93. **Churning of Sweet Cream.**—Butter made out of perfectly sweet faultless cream possesses the pure taste of butter, free of all foreign flavours, and is the finest butter which can be made. Since, in churning sweet cream, the souring of cream, the development of which is attended with so much labour, inconvenience, and uncertainty, is quite unnecessary, it is highly desirable, from a practical

point of view, that sweet-cream churning should become general. Even although sweet cream is not so easy to churn, and yields always, even under the most favourable circumstances, less butter than sour cream of a similar percentage of fat, yet this is amply compensated for by the great advantage which is offered by being able to dispense with cream-souring. The fact that, notwithstanding this, sweet-cream churning is at present only practised to quite a slight extent, is chiefly to be accounted for by the fact that by far the larger majority of consumers prefer the light aromatic flavour of butter made from sour cream, and that only a few know how to appreciate the fine flavour of sweet-cream butter. In the year 1874 the director of the manufactory for making preserved butter in Copenhagen, Herr Busck, junr., put himself to a great deal of trouble to introduce the churning of sweet cream into the dairy districts of Denmark and South Sweden. For several years this movement seemed to make good progress, but even as early as the year 1882 this method of butter manufacturing was being given up, and at present, so far as the author is aware, in all dairies where sweet-cream butter was formerly made, sour cream is now again churned. The careful experiments carried out in Denmark at that time showed that the yield of butter from sweet cream, when the improved Holstein butter churn was used, was only 2 or 3 per cent less than that from sour cream containing a similar percentage of fat, provided the sweet cream was churned at an initial temperature of 11·25° to 12·50° C., and the churn was worked at the rate of about 150 revolutions per minute, churning being carried out in 25 or at the most 30 minutes. The butter-milk left behind from sweet-cream churning assumes very commonly, in a very short time, a bitter acrid taste, which becomes especially distinct if the butter-milk be slowly warmed. This is probably to be traced to the action of certain kinds of bacteria, which can develop in liquids showing an amphoteric or neutral reaction, but not in those possessing an acid reaction. Even in sweet-cream butter, which has been kept for some time, a bitter flavour is often found in addition to the rancid flavour.

94. Churning of Milk.—As has already been pointed out in § 90, it is not economical to churn absolutely sweet milk, since it has not yet been found possible to obtain from it even approximately the same quantity of butter as is obtained in the churning of sour milk. As a rule, milk 24 and 36 hours old is churned, viz.

the morning milk of the one day and the evening milk of the previous day. The milk is poured into large wooden vessels, or cylindrical metal vessels, to the depth of about 60 centimetres in summer, and in winter somewhat higher—about 75 to 80 centimetres, and is allowed to become spontaneously sour, but is not treated with the sourer. When it is churned the milk should not have become liver-thick, that is, it should be in a condition between the firm and the liquid condition. If the Holstein churn is being worked, the churn should be revolved at the rate of about 100 revolutions per minute, and the initial temperatures should be within the limits of 15° to 18·75° C., so that the churning may be finished within 45 or at most 60 minutes.

The churning of milk requires very little space and very few utensils. It makes a small demand on the technical knowledge of the dairy staff, and offers generally, on account of its extreme simplicity, great advantages. On the other hand, it affords only a one-sided utilization of milk. Although it occasionally yields a very fine butter, milk-churning, on an average, produces a butter inferior in quality to that from cream-churning. The butter-milk must be used either as a food for pigs or worked into curds, or into sour-milk cheese. Formerly this method of utilizing milk was very general, and was very popular owing to its simplicity; at present it is becoming less and less so, and it can scarcely be regarded as economical, except under very exceptional conditions.[1] In no country in which dairying is in a recognized forward condition is milk-churning carried on to any extent. How old this method of butter manufacture is it is difficult to discover. This much, however, is known, that in the previous century it was in use in different districts of Belgium, Holland, and probably also Northern France.

The yield of butter in the churning of milk is somewhat less than it is in the churning of sour cream obtained by separators, and somewhat higher —as in the proportion of about 100 to 102—than in the churning of sour cream which has been obtained by the older methods.

95. Experiments made to Obtain Butter by Methods other than those Commonly in Practice.—During the year 1889 two new kinds of apparatus were brought out, by means of which butter was made under conditions essentially different from those obtaining for centuries, in the manufacture of butter. These were the Butter

[1] In certain districts in Ireland and in Scotland, especially in mining districts, where there is a good demand for butter-milk for human consumption, this method of treating milk is regarded as the most remunerative.—*English Editors.*

Extractor of Jacobson, first exhibited at the Royal Agricultural Society of England Show at Windsor, from the 24th to the 29th June, 1889; and in Germany first at the Provincial Schleswig-Holstein Exhibition at Kiel on the 20th to 23rd March, 1890; and the Butter Separator of Dr. De Laval, first exhibited in Germany at the Fourth International Exhibition of the German Agricultural Society at Strasburg in Alsace from the 5th to the 11th of June, 1890. Both of these machines cream the milk by centrifugal force, and immediately churn the cream thus obtained; and in both, the arrangement for churning is of such a nature, that the cream is beaten with extraordinary violence. In the butter-extractor (fig. 51) the cream is separated on the spot in the inside of the separator-drum, and in the butter-separator the cream leaves the separator-drum in the usual way, flows over a cooler, and falls thence into a small open butter cylinder attached to the separator frame or stand. The bowl of this butter cylinder is set in motion by means of a spring from the bowl of the drum. As is well known, the temperature at which creaming of milk takes place is not the same as that at which churning is done; since the most favourable temperatures for the separation of cream and for churning are not the same. The arrangement of the butter-extractor is of such a nature that creaming must take place always at that temperature which is required for churning, while, on the other hand, in using the butter-separator there is nothing to prevent the regulation of the temperature in a suitable manner to what is best suited to promote the success of the successive processes. From this point of view, therefore, this apparatus possesses an advantage over the former. As has

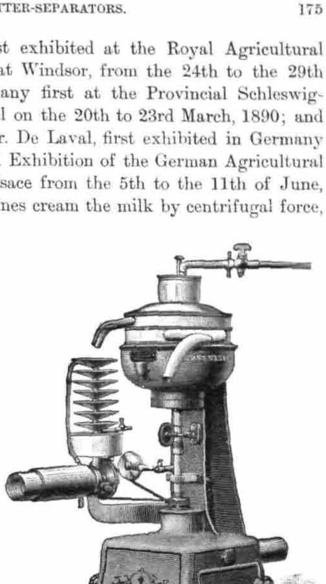


Fig. 51.—Centrifugal Butter-separator.

been previously mentioned, butter should leave the extractor at a temperature of from 20° to 21° C., and the butter-separator at a temperature of from 16° to 17° C. In the small butter cylinder of the butter-separator, the paddle apparatus of the separator, when working at its most favourable speed, makes 3600 revolutions per minute, and in the butter-extractor the rate of revolution is still greater.

The author has seen the butter-extractor repeatedly in operation, but has not been able to examine it minutely; on the other hand, he is familiar with the working of the butter-separator. According to his observation the extraction of butter by this apparatus differs from the ordinary operation of churning in the following points:—

(1) In the butter-separator, the separation of butter is carried out by means of a mechanical arrangement, which is more violent than that used in the ordinary churning.

(2) The formation of the little lumps takes place much more quickly than in the ordinary processes of butter production.

(3) The little lumps of butter do not attain to the same size as in the ordinary processes.

(4) The cream is only subjected to the mechanical action for a short time.

The real service which the butter-separator performs consists in the fact that it renders it possible to churn perfectly sweet cream, and to obtain excellently satisfactory results in proportion to the quantity. Although this service is an important one, it can scarcely be said to mark an important advance in the practice of dairying. This would only be effected if it were shown that the new apparatus yielded butter, the properties of which complied with the requirements of technique, of commerce, and of flavour. The experiments carried out by the author have shown that the little lumps of butter yielded by the butter-separator retain far more butter-milk than those little lumps obtained in churning in the usual way, and therefore that the butter of the butter-separator is, on an average, somewhat more watery than ordinary good butter. Even although the butter-milk could be more perfectly separated from this kind of butter, a point which does not seem to be unattainable, the butter-separator would still probably only have a limited use, since there is a very slight demand for perfectly sweet butter prepared from perfectly sweet cream, owing to the fact that the public taste in Germany does not lie in that direction.

96. Colouring of Butter for Use.—The requirements of a wholesale trade, which has to provide throughout the year a good butter of uniform appearance, has brought about a demand which in the course of time has given rise to the practice of adding suitable substances to butter to impart a definite uniform colour. Formerly it constantly varied in colour. This requirement is burdensome and inconvenient to dairies, but it must be complied with so long as the large dealers in the finest butter for export purposes will only pay the best price when the butter possesses the required tint. Butter which is used for home consumption is not coloured, and it is stupid, and serves no end, to colour it with pigments such as the so-called butter colours.

The following qualities are necessary in a butter colour, viz. that it should colour the butter yellow without imparting to it a foreign taste or smell, that it should contain no substances deleterious to health, that its appearance should not be non-appetitizing, that it should be easy to apply, that it should possess strong colouring properties, and that its price should be in proportion to its true value.

In the Hamburg market, the butter going to England has to possess a yellowish straw colour, and that going to Spain and Portugal, and also a part of that going to South America, has to be orange yellow. Formerly, in butter exported to different countries—to France, Holland, and North Germany—all sorts of colouring matters were added, such as saffron, carthamus, logwood, turmeric, carrot-juice, extract of marigold, and annatto, which were generally added to the butter by kneading in. At present, where butter is coloured, it is generally done in the churn, and the liquid in the churn receives an exactly measured quantity of the colouring matter directly before churning, which is without doubt the most efficacious way. The colouring matters used in Germany, Denmark, and Sweden are entirely solutions of the fruit flesh of the annatto tree, indigenous to South America and the East Indies, dissolved chiefly in hemp or sesame oil, and with varying quantities of turmeric colouring matter added to the solutions. In using this kind of colour, for butter destined for England, on an average about 4 grams are required or added for every 100 kilos. of milk, or for the cream yielded by this quantity of milk. The butter contains, therefore, reckoning 3·5 kilos. of butter for every 100 kilos. of milk, ·12 per cent or 1·2 gram of colouring matter per kilogram; that is, assuming that none of the colouring matter is left behind in the butter-milk. As this, however, is always the case, the butter used in the English market contains on an average about 1 gram of colour per kilogram. If the price

of a litre of artificial colouring matter be taken at 4 to 5 marks, the colouring matter used for 100 kilos. of butter will cost about 80 pfennigs.

97. **Salting of Butter.**—Over the whole of South Germany, Switzerland, and in the countries of the Austro - Hungarian monarchy, the butter is not salted. On the other hand, in North Germany, Denmark, Sweden, England, Holland, and in some districts of France, salt butter is chiefly used. The quantity of salt added differs — that used for immediate consumption containing 1 to 3 per cent, that used for export containing generally 4 to 5 per cent, sometimes, however, more, even as much as up to 10 per cent. The object of salting is to preserve, render the butter better, and to impart to it a flavour—the salt flavour. By means of salting, raw butter is more thoroughly separated from the butter-milk which adheres to it than it would be possible without the application of salt. Four to five per cent is quite enough to ensure for butter keeping properties that are sufficient for all practical purposes. Good butter salt should not only be pure, but should also possess the proper degree of fineness, and should be rapidly soluble in water. Butter salt of too coarse a grain does not dissolve perfectly in the moisture of the butter, and too small grains form small drops of brine which are difficult to incorporate by kneading. It is obvious, of course, that the salt kneaded into the butter is not to be wholly found in the finished butter, since a large portion of it becomes dissolved in the water used in the kneading, and is thus lost. Raw butter, to which 4 per cent of salt has been added, contains, when properly kneaded, scarcely 2 per cent. The liquid expressed by kneading contains, according to investigation, about 90 per cent of water, ·15 per cent of protein matter, ·6 per cent of milk-sugar and lactic acid, and 9·25 per cent of mineral matter, exclusively salt. During salting and kneading, the raw butter suffers, on an average, a loss of weight of from 2 to 4 per cent; indeed, under exceptional circumstances, the loss may amount to as much as 9 per cent.

If butter salt has to be tested for its usefulness, it should be chemically examined for purity and tested by means of the microscope. It should be of a pure white colour and free from mechanical impurities, and when dried should contain from 98 to 99 per cent of sodium chloride. Salt with a musty smell or mixed with sand, or containing several per cent of gypsum or sodium sulphate, calcium chloride, and magnesium chloride, and which in consequence absorbs moisture rapidly from the air, is not suited for

salting butter. To further examine it, three sieves of different meshes of 2, 1, and ·5 mm. in diameter are used to determine its fineness. Its apparent specific gravity and relative solubility should also be determined. The salt best suited for salting butter is that which consists of not too small but very thin and delicate crystals. Such salt is largely composed of little pieces, which remain behind on the coarsest sieve, exhibit a relative small specific gravity, and dissolve rapidly in water. In North Germany, the butter salt coming from Lunniberg and Stade is rightly much appreciated.

In England, Sweden, and America, in order to give to the butter greater keeping properties, it is common to add not salt alone to the butter, but also a mixture of salt and sugar, or a mixture of salt, sugar, and saltpetre. Since, however, as has already been pointed out, it is possible to impart to butter the desired keeping quality by the addition of salt alone, all other substances, sugar excepted, must be regarded as inadmissible.

98. **The Working and Kneading of Butter.** — The object of working butter is to unite the countless little lumps, of the size of a pin-head, formed in the raw butter during churning, and to remove the butter-milk clinging to them as perfectly as possible. It is also desired to convert them into the finished product, which shall possess a similar texture throughout and be in the best condition and of irreproachable appearance. This is best effected by artificial pressing and turning during the working of the single lumps formed in the raw butter. The working is sometimes associated with washing butter. In the preparation of salted butter, the effect of working depends upon the fact that each grain of salt attracts moisture from its surroundings, which dissolves it and forms a larger drop of brine. The working of butter will be understood, when it is remembered that on the one hand every single grain of butter contains a larger or smaller quantity of small drops of butter-milk, according as churning has been more or less successfully carried out, and that, on the other hand, a certain quantity of butter-milk mechanically clings to the surface of every single little grain. The butter-milk enclosed in the little grains of butter is in far too fine a state of division to permit of its being diminished to any extent by working, even although this may be carried on for some time. At most it may be perhaps somewhat diminished by the osmotic action which salt exerts. On the other hand, it is very easy to remove the butter-milk clinging to the external surface of the little

lumps, and this should be done as effectively as possible. As soon as this is effected butter should no longer be worked. A longer period of working is not only useless, but is even deleterious, since it influences in an injurious manner the characteristic structure possessed by good butter. The art of working consists in expressing the butter-milk contained in the butter into large drops, in such a manner that they unite together, and then by so turning it that the drops formed in this way flow out owing to their gravity. The formation of large drops is effected by making numberless deep impressions for a sufficiently long time on the pieces of butter. It is quite a mistake and is useless to press the butter on all sides at the same time, in working it, or to squeeze it out in thin layers, or to treat it in any other way violently. The most excellent kinds of butter contain not less than 10 and not more than 15 per cent of water. Overworked butter, that is, butter which has been too long and too powerfully kneaded, possesses a stale dry appearance; and butter, when insufficiently worked, is soft and oily.

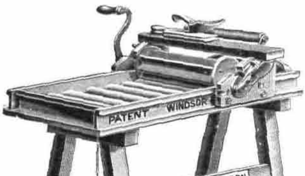


Fig. 52.—Butter-worker.

The operation of working should always be effected entirely—and this would be best,—or chiefly with butter-workers (figs. 52 and 54) instead of with the hands. There is quite a large number of such utensils, of which several are not quite suited for the purpose, as, for example, the butter-syringe of Handcock and Von Bohlken and others, the Eureka butter-worker, the Reid butter-worker, and the Swiss butter-worker, all of which fall far short of what is required. Only two butter-workers can be recommended as well suited for their purpose, and as meeting in a satisfactory

Fig. 53.—Butter-knife.

way the requirements of such utensils, viz. the utensil invented

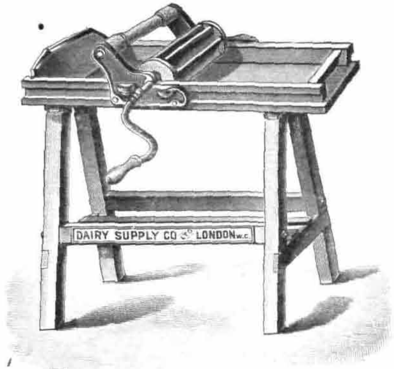


Fig. 54.—Butter-worker.

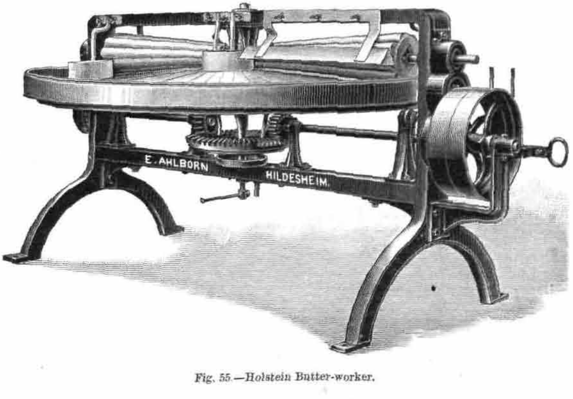


Fig. 55.—Holstein Butter-worker.

in America and improved in Denmark and Germany, with ribbed roller moving in a circle over a round table (fig. 55). This utensil

is adapted for use on a large scale. The other one is also American, and has been improved by Amsinck, and consists of a kneading-board, and is suited for use on a small scale. The apparatus recommended by the Frenchman Baquet, which separates the raw butter from the butter-milk in a centrifugal apparatus specially adapted for the purpose, by means of centrifugal force, has on careful investigation not been found to be generally suitable.

The work of kneading is best carried on when the butter has a temperature of from 10° to 15° C. The room in which the butter is kneaded must therefore be kept cool in summer and heated in winter.

Washing the butter thoroughly during kneading affects its fineness, perhaps also its keeping qualities, and can only be justified if the souring of the liquid which has been converted into butter is not pure, or has been carried too far.

A proved method of working in the production of salted keeping butter is the following:—

The raw butter is separated by taking pieces weighing from 1 to 2 kilos. gradually from the churn, and placing them in the mould-shaped beechwood butter-trough (fig. 56), after the butter-milk has run away of its own accord. The first piece is laid on the side of the trough, and a pressure is applied with both hands, one laid on the top of the other.

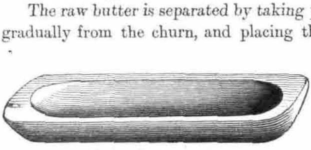


Fig. 56.—Butter-trough.

The flatly-pressed piece is rolled together and placed upright, and this is repeated six or ten times. This is repeated with each remaining piece till the whole mass is entirely worked and the first kneading is ended, thereupon the thoroughly-kneaded butter pieces are brought to delicate scales placed in the kneading-room, weighed, the necessary quantity of salt according to the weight is added, that is, for every kilo. 20 to 40 grams, or 2 to 4 per cent of dry good salt is added, and the weighed-out quantity of salt is mixed in a graduated glass cylinder. The half of the pieces of butter are then brought into the upper part of the butter-trough, half the salt is strewn thereover, the other half of the butter is then added as an upper layer, and this is strewn with the other half of the salt as uniformly as possible. It is scarcely necessary to say that, according to circumstances, the butter may be mixed with the salt in three or more layers. Similarly, it is hardly necessary to mention that when the butter is to be kneaded the hands should be first warmed and then washed in cold water. As

soon as the salt has been strewn, pieces weighing from 4 to 5 kilos. are gradually added from above in successive layers, and a strong pressure, made by pressing with the one hand on the top of the other, is applied eight or nine times on the side of the trough. Before every new pressure the piece which has been pressed flat is changed to different sides, and pressed again in order to incorporate the salt in the most thorough manner possible. When the whole mass has been thoroughly worked, salting and the second kneading is at an end. The single pieces of butter are left in the trough lying beside one another, from 4 to 6 hours, and are not further worked with the hand, but only with a butter-worker or with an American butter-board. A single working on the butter-board at the end of the proper time is sufficient. If the pieces of butter as they come from the working in of the salt lie beside one another and not on the top of one another, the whole mass of the butter receives a similar consistence. If the butter should be too soft in summer, the proper degree of firmness may be imparted to it by cooling it in a suitable method from above with ice. In winter the butter-working should be carried on in a heated room. If the butter is too cold in winter it should be placed in a metal vessel on a damp board, and laid in water at 15° or 16° C. until it has received the necessary amount of softness for working. If the butter has to be worked later on in the kneader, it should be spread in portions or layers not too thick over the table, after being prepared by being treated with sufficiently hot or cold water, care being taken that the holes for permitting the draining away of the butter-milk are not choked up. When the butter-worker is not fitted up for machine use, kneading should be carried on by two persons, one turning the handle at a medium rate, and the other, by means of a wet wooden spatula, spreading the strips of butter on the board of the worker as soon as it has passed once through the rollers, in pieces of about 30 centimetres long. These are subjected to a uniform rolling for a quarter of an hour and again placed in the pressing rollers. This rolling and pressing must be carried out with care, in order that the liquid drops on the butter may flow away and be separated. The operation may be regarded as finished as soon as, after strong pressing together of pieces of butter about the size of the fist, no more drops of brine are seen, which is generally the case after the whole mass has passed eight or ten times through the rollers. The room in which the butter lies after salting must be fresh, clean, and free from dirt; care also ought to be taken that the butter should not be exposed for a long time to the action of bright daylight. In summer-time, it is occasionally advisable to cover with gauze the trough in which the butter is lying. The butter should be packed away in the previously prepared box or tub as soon as possible, on its removal from the kneading-board. It is advisable not to touch the butter with the

hands during working, but to carry out the first and second kneading on the butter-worker.

99. **Yield of Butter.**—Of a very large number of churns which have been constructed and recommended in the course of time, only a very small number have succeeded in establishing themselves in general practice. With all the useful churns, if properly handled, a yield of butter can be obtained from a fluid, which approximates to the percentage of fat it contains. This explains how the amount of the yield of butter in proper churning is almost always solely dependent on the percentage of fat in the milk, and on its successful removal in the cream. From experience, and a large number of experiments, it is known that it is easily possible to obtain about 97 per cent of the entire fat in the form of butter when sour cream containing 15 to 25 per cent of fat is employed; 89 per cent when sour milk is used, and 86·5 per cent when sweet cream of 15 to 25 per cent of fat is employed. If the percentage of fat in milk be denoted by the letter f, and the finished butter contains 84 per cent of fat, the yield of butter x, in the case of churning with sour milk, may be easily obtained by the following formula:—

$$x = 1 \cdot 06 \times f$$

and in the case of churning soured cream, when the percentage of fat in the skim-milk obtained is ·25 per cent, by the formula:—

$$x = 1 \cdot 155 \times f - \cdot 2454.$$

It would be very simple and easy to calculate similar formulæ for other cases. Such formulæ are extremely important and useful for occasional testing of the results of the manufacture of butter in dairies. By calculating the yield of butter, for example, in the case of a known percentage of fat in milk, and by comparing the result obtained with that actually yielded in practice, it is shown whether what is, as a rule, easily obtainable, has been really obtained or exceeded, or whether, owing to existing unfavourable circumstances, it has not been obtained.

In practice, the yield of butter is generally found by weighing the butter obtained, and by dividing the number denoting the weight of the milk used by the number denoting the weight of the butter. In this way we learn how many parts by weight of milk have been required for each part of butter by weight obtained. By dividing the number

denoting the quantity of milk into 100, or by looking up in the author's tables the number standing beside this number, the percentage yield of butter is obtained. In dairies in which butter is salted, the butter is weighed always after the first working, and before the salting, for the purpose of estimating the proper quantity of salt to add; and this figure may be used for estimating the yield of butter. Since butter in the unfinished condition generally contains somewhat less fat than the finished article, the yield of butter will be found to be somewhat higher in this way than by weighing the finished article. In a properly conducted dairy, the creaming of milk and churning should be carried on throughout the year in a similar manner, so that any variation in the yield of butter should be due to the variations in the percentage of fat in the milk and to the season of the year. On this account, if in such dairies the percentage of fat in the milk to be worked aproximates very nearly to the amount of the yield of butter, care should be taken not to draw an exact conclusion from these grounds, but also to take into account, in judging of the percentage of fat in the milk, the results given by the butter-testing apparatus.

100. Different Kinds of Butter.—Butter, in the first place, may be distinguished as milk-butter and cream-butter, according as it is obtained from milk or cream. Milk-butter is prepared from sour milk, while cream-butter may be further divided into butter made from sweet cream and butter made from sour cream. Since there are still few dairies in which separators are used, butter coming from such dairies is known as separator-butter. It would be desirable that such butter should be designated by a particular name, since it is regarded as inferior to that made by the old—that is, the Holstein—method. Finally, butter may be distinguished as fresh butter and keeping butter, unsalted butter and salt butter, and coloured and uncoloured butter. The following kinds of butter may be distinguished in the butter market:—

(1) *Fresh Butter or Table Butter, Tea Butter, &c., adapted for immediate consumption.*—Such butter contains either no salt at all or only very small quantities. It is either entirely uncoloured, or in winter-time slightly coloured. The finest kinds of this butter are prepared from perfectly fresh sweet cream, and it is neither salted nor coloured. The so-called Petersburg butter or Paris butter, which was formerly chiefly prepared in Finland, is unsalted cream-butter, possessing a characteristic, not unpleasant, light taste. By means of the peculiar treatment which the cream used in its

preparation undergoes, it possesses keeping qualities in a very high degree. The cream, before churning, is heated to the boiling temperature of water, or approximately to that heat, when it is rapidly cooled and churned in the ordinary way. Naturally, it is only perfectly sweet cream that could stand such treatment.

(2) *Preserved Butter*, or butter prepared from milk or cream, is always salted, and generally also always coloured, and is expected to retain its pure flavour for four weeks or longer. Such butter is suited for export to England, and for transhipment by sea to other countries. The butter which keeps best is made from soured liquid, especially soured cream, since in it, through the action of the lactic bacteria, all the remaining kinds of bacteria are retarded in their development, and since, owing to its sour reaction, a large number of deleterious kinds of bacteria are entirely prevented from developing, so that as a result of this the fat is only changed by gradual oxidation. Good preserved butter should only become rancid with the lapse of time, but should not develop any other flavour, such as a soapy or bitter flavour. In the Hamburg butter-market, butter is distinguished as winter or byre butter and summer or grass butter. The winter butter is divided into old-milk and fresh-milk butter, and the summer butter into May, early-summer, late-summer, and stubble butter. The best-keeping kinds are the early-summer, late-summer, and especially stubble butter. That which is not exported to foreign countries comes upon the market in casks and barrels of wood, which in certain large European butter markets must be of a certain prescribed size and quality.

Butter which is prepared for provisioning ships, and for export to other parts of the world, has been known since 1873 as preserved butter. This kind of butter is not prepared in any special manner, and is not treated in any way, but simply consists of selected quantities of fine butter, which, in the judgment of competent butter experts, may be expected to possess, with great probability, good keeping qualities. This butter is always salted, and occasionally, although not frequently, is treated, in addition to salt, with sugar and saltpetre. It is always coloured. It is packed in air-tight, soldered, round, metal barrels of different sizes, which hold from 1 to 23 kilos. of butter, and which are generally coloured outside with aniline colour.

In Bremen, Hamburg, Kiel, Copenhagen, and Stockholm, and in other

European ports, large butter manufactories supply preserved or box butter for transatlantic shipment. One of the earliest and most important undertakings for supplying such butter was that founded in 1873 in Copenhagen, under the directorship of Mr. Busck, viz. the Scandinavian Preserved Butter Company. The activity of this excellently conducted business exercised during the period of its existence a widespread influence on the dairy industry of Denmark and of South Sweden. To such an extent was this the case, that for several years only butter was put on the market which had been made under the ice system from sweet cream which had stood for 10 hours, and in consequence the practice of sweet-cream churning was carried on for a time to a considerable extent.

The transmission of table butter in post-boxes, or in boxes by post, which do not hold more than 5 kilos. nett, to private consumers, has developed very considerably in Germany during the last ten years.

The different names applied to the different kinds of butter which are used in the retail trade, as, for example, *horst* butter, *lackierte* butter, *gold-brand* butter, &c., are of comparatively little importance.

(3) *Whey Butter.*—In all districts where fatty hard cheeses are prepared, for example, in South Bavaria, in Switzerland, in Austria, and in Holland, butter is obtained from the whey, which contains a small portion of the milk-fat which has not been removed in the manufacture of the cheese. Separation of the fat from the whey may be effected in three different ways. The whey may either be warmed to 68° to 75° C., treated with 1 per cent of sour whey, and further warmed to 80° to 95° C., skimming the fattier portion of the so-called *vorbruch*, which at this temperature collects on the surface, and amounts to about 3 per cent of the entire volume of the whey; or the whey may be allowed to stand 24 hours in cold water to cream, and the rich fatty surface layer may then be skimmed off; or the whey creamed by the separator, as is done with milk. Both the *vorbruch* and the whey cream are churned in the ordinary manner. The whey butter obtained from whey cream is better than the *vorbruch* butter. Butter obtained in the latten way represents a lesser yield than butter obtained in the former way. It may be calculated that in the preparation of fat cheeses, according to the Emmenthaler method, ·75 kilos. of *vorbruch* butter is obtained from every 100 kilos. of milk, and ·8 to 1 kilo. of whey butter. Both these kinds of butter do not differ in their average composition (chemical) from ordinary butter. Possibly they are often a little richer in protein bodies. In fineness and pureness of flavour they

are no doubt distinctly inferior to ordinary butter, and this is more so the case with *vorbruch* butter than with whey butter. These two kinds of butter are often not churned alone, but mixed with cream or milk, the butter obtained being of average quality.

101. **Melted Butter.**—The butter obtained by the melting of butter-fat, melted butter, forms throughout the whole of South Germany and Austria a very important and much-sought-after article of commerce, which has long been in use. Good, pure melted butter contains 98 to 99·5 per cent of butter-fat. The best kinds are obtained by melting good butter on the water bath at 40° C., allowing it to remain for several hours at this temperature until it becomes perfectly clear, and then carefully skimming the foam or scum which collects on its surface, and separating it from the sediment by pouring it off. The scum and the sediment furnish a useful fat for kitchen purposes. In the preparation of melted butter on the large scale, a loss of from 17 to 20 per cent on the butter used is experienced, and on a small scale 20 to 25 per cent. Occasionally, in the preparation of melted butter on the large scale, difficulties arise, such as the failure of the butter-fat to solidify when slowly cooled, the formation of a liquid, and of a solid part, which separates out from the liquid portion, the so-called butter-oil obstinately remaining liquid.

What is known in the Hamburg butter-market by the name of Siberian butter, is melted butter which is brought from the interior of Russia *via* Archangel and St. Petersburg.

102. **Butter-milk.**—The fluid left behind after churning—the butter-milk—contains chiefly the smaller fatty globules of the milk, and possesses a specific gravity which is somewhat higher than that of ordinary milk, varying between 1·032 and 1·035 at 15° C. It appears, according to the method of churning, either perfectly fresh or more or less sour. Sour butter-milk, on account of its weak seedy condition, closely resembles in appearance poor cream, or very rich fatty milk. Butter-milk, made from sweet cream, easily assumes an unpleasant bitter flavour, which is especially developed when the butter-milk is warmed. Butter-milk obtained from proper churning contains as a rule from ·5 to ·6, in no case more than ·8 per cent of fat. Common practice, which still favours to a large extent the unseemly custom of pouring in large quantities of warm or cold water into the churn during churning, often yields butter-milk of an exceptionally poor percentage of fat.

Butter-milk is chiefly used for feeding pigs. It is also used in small quantities for cheese manufacture and as a human food. Its feeding value is very different, according as it has been more or less watered. Unwatered butter-milk can occasionally be sold for the feeding of pigs under the most favourable conditions at 3 pfennig per kilo. It is pretty near the truth to say that, taking the value of pork at 35 to 40 marks per 50 kilos. of live weight, its feeding value may be estimated at 1·5 to 2·5, on an average at 2 pfennig per kilo. Very sour butter-milk should be boiled before feeding, especially if used for calves, and should not be used in too large quantities at once, but rather oftener,—four to five times per day,—in small quantities. Its nutritive ratio is about 1 to 1·5.

The average composition of butter-milk and of its ash will be seen from the following analysis:—

Water, ...	91·24
Fat, ...	·56
Protein, ...	3·50
Milk-sugar and lactic acid, ...	4·00
Ash (mineral matter), ...	·70
	100·00

Composition of the ash:—

Potassium oxide, ...	24·53
Sodium oxide, ...	11·54
Calcium oxide, ...	19·73
Magnesium oxide, ...	3·56
Phosphoric acid, ...	29·89
Chlorine, ...	13·27
Iron, sulphuric acid, and loss, ...	0·47
	102·99
Deduct oxygen replaced by chlorine, ...	2·99
	100·00

103. The Properties of Good Butter.—Good butter should possess a uniform appearance, neither patchy nor striped. Its *colour*, which is influenced by the feeding, and perhaps also by the individuality of the cow, is in winter yellow, occasionally almost pure white, but in summer it is yellowish to absolute yellow. In artificially coloured butter, an entirely yellow or reddish-yellow tint is required in the different markets. Good butter should neither be dull nor entirely

sparkless in appearance, but ought not to possess too strong a glitter. It should have a tender, mild glitter, which it has when it possesses the characteristic ripe grain, which distinguishes it from all other fats. In properly prepared butter the exceedingly fine division which the fat originally possesses in the milk should not be entirely lost, but should be distinctly recognizable. To this may be ascribed the fact that butter-fat is very easily emulsified by the gastric juices, a characteristic that distinguishes butter-fat from all other fats, and renders it easily digestible. Good butter should neither be too soft, that is to say, smeary and of the nature of a salve, nor too hard, that is, dry and friable. The drops of moisture and of salt brine present in butter should not be too large nor too abundant, but must be quite clear, and should not possess in the slightest degree a milky appearance. Salted butter should not contain undissolved salt.

The smell or odour of butter is in close relationship to its flavour, and should only be very slightly developed in good butter, and then it should be of a pure characteristic butter odour.

The flavour of good butter should be that of pure butter only, and should not be associated with any kinds of foreign or unusual flavours. Apart from the fact that salt butter is distinguished from unsalted butter by its salt flavour, butter possesses an essentially different taste, according as it is prepared from sweet or sour liquids. Butter made out of sweet cream is characterized by a clean, extremely mild, and by no means strong flavour; butter made out of sour liquids possesses a certain aroma and a powerful characteristic flavour, which in many districts is demanded as an absolutely essential quality. Regarding the origin of this aroma, so far as is known up till now, it can neither be traced to the food, nor is it already formed in the milk. It seems to be first formed during the process of souring, in consequence of the change and the mutual decomposition of the constituents of the milk, probably of the milk-sugar, and its origin is connected with lactic fermentation. Whether perhaps some of the neutral fats present in butter are decomposed at the beginning of the decomposition, and whether lactic fermentation alone is its cause, or whether it is not also connected with other kinds of fermentation, as, for example, alcoholic and butyric fermentation, is not altogether yet fairly demonstrated. We know nothing with regard to the chemical nature of this aroma. Petersburg or Paris butter has a weak flavour of boiled milk.

Butter made from the milk of cows that have been in milk for a time is generally firmer than that from the milk of recently calved cows, and usually possesses also a less fine flavour. With regard to the influence of the feeding of the cows on the condition of the butter, it has been proved that colour, smell, flavour, keeping qualities, and in a very special degree the solidity of the butter, are dependent on the properties of the food consumed by the cow. In a much greater degree, however, the condition of butter is influenced by the treatment of the milk before churning, by the kind of churning, and by the method in which the raw butter is worked. These conditions have a greater influence than the food.

In addition to the above-mentioned points, the appearance, the smell, the flavour, the solidity, the fat percentage, the quantity, and the condition of the brine of the butter and its keeping qualities, have all to be taken into account in judging of its condition. The condition of butter depends on the condition of the milk, as well as on the method of treatment, the feeding of the cow, on the lactation period, probably also on the breed, the individuality, and the age of the cow, but above all on the method in which the butter is manufactured.

In order to test the firmness of butter, it is repeatedly pressed with the flat side of the blade of a knife, and a piece is cut off in order to see whether the butter sticks to the knife. By pressing, it is easy to obtain for inspection a drop of brine. If the flavour of butter be desired to be tested, a small piece is taken with a perfectly clean knife, spread on the small finger of the free hand by means of the other hand, lifted to the mouth, not with the knife, left a short time on the tongue, and then swallowed, the butter being pressed against the gums in the act of swallowing. If preserved butter tasted, after 8 to 14 days, perfectly pure and fine, and if it possessed the proper appearance and grain and the required firmness, and especially if the brine be perfectly clear and not in too large a quantity, it may be asserted with a high degree of probability that it will keep excellently, and that it is suited for use as preserved butter, that is, for packing for export in metal boxes. Butter with milky brine may possess all other good properties, but it never keeps long.

Although we know little for certain with regard to the special action of individual foods on the condition of butter, the remarks which have already been made in § 18 may be regarded as worthy of attention.

104. The Common Faults of Butter.—The undesirable properties which are observed in butter are for the most part caused by

mistakes made in the preparation of it, and are only due, to a small extent, to the use of foods unsuitable for milk-cows. These properties or diseases develop in a very characteristic manner in the keeping of preserved butter. The following are the indications of bad butter, which are recognized on the larger butter markets, as, for example, in the Hamburg market.

The butter is described by the following terms:—

Faults in Appearance.—If it contain milky brine, *dull* and *cheesy*; if too much worked, *opaque* and *thick*; if glittering with fat, because it has been spoiled in the churn or has been too little worked, *fatty* or *oily*; and in the case of coloured and salted butter, apart from the proper shade of colour that it ought to possess, *flecky*, *streaked*, *cloudy*. These faults are the result of unskilful colouring or salting, or working the butter in winter in unheated rooms.

Defects in Firmness.—*Dull* when soft and rich in milky brine; *oily*, *too soft*, *overworked*, *dry* and *hard*, *burned*, that is, dry and friable, and *short* or *crumbling*.

Defects in Flavour and Smell are as follows:—*Rancid* or *bitter*, terms that are used respectively according to the weaker or stronger development of the flavour; *dull*, *rank*, *bitter*, *uninviting*, *greasy*; *lardy* when there is a weak tallow flavour, and *tallowy* when there is a strong tallow flavour. The butter is inclined to develop this flavour if the cows eat much young fresh clover, or if they be supplied with large quantities of tallowish-flavoured oil-cakes. Furthermore, the butter becomes tallowish if it lie for a long period in bright light, or if it be submitted for a short time to the sunlight. Butter, also, which has been frozen and again thawed is occasionally tallowish; *oily* when it is accompanied with a strong development of this quite peculiar characteristic flavour; *fishy* and with the flavour of train-oil. The oily flavour, which only butter made out of soured liquid assumes, is characterized to a certain extent by an increase of the peculiar aroma belonging to this kind of butter, which finally becomes positively repugnant. It is caused by certain kinds of bacteria, which develop, along with the lactic ferment, during souring, especially in summer. As soon as it is noticed a sourer (pure) should be added, preferably a pure culture of lactic ferment for souring the cream. *Woody*, that is, spoiled by the boards of the kegs in which the butter is packed. The woody flavour, which is somewhat distantly suggested by the peculiar after-flavour of Roquefort cheese, is only developed if moulds grow on the surface or in the inside of the butter. This defect is engendered by packing the butter in casks made out of young damp wood inclined to be musty, and also by not compressing the butter firmly enough into the

casks. *Cheesy*, possessing a bitter acid sour flavour of the country; an unclean oldish flavour which is not very characteristic. *Tasting of the food*, generally bitter, and caused by undue feeding of cows with certain kinds of foods, such as cabbages, frozen or otherwise damaged beet-root, sour food, distillery refuse, &c.; *tasting of the byre*, with the flavour of cow-dung and the atmosphere of the byre; *smoky*, if ovens in the rooms in which butter is kept are bad and smoke; *soapy*, caused by careless washing of the dairy utensils with soap or soda; *smelling of oil-paint*, if grease has been brought into contact with the cream or butter, or if the milk has been kept in vessels freshly painted with oil-paint; and *musty*, if the butter has been kept in damp, badly-aired rooms.

Other defects are *mouldiness*, if the butter be white, green, grass-green, or red, owing to bacterial growth; *blue*, from blue milk, very uncommon; *oversalted*; defective salting, if the finished butter still contain grains of salt; and lastly, *dirty*, if the butter contain threads, hairs of cows, dead flies, soot, &c., or shows patches of rust, or generally gives indications of dirty handling.

105. **The Chemical Composition of Butter.**—The chemical composition of butter varies according to the method in which it has been manufactured. Nevertheless, under all circumstances, milk-fat or butter-fat is its chief constituent. Like all other common milk products, butter contains all the constituents of milk, and if its fat be left out of consideration, it contains the other constituents in the same proportion as they are present in milk. Butter may be described as a kind of solid milk. It is owing to the fact that it contains, in addition to the fat, a certain quantity of water and a small quantity of protein matter, milk-sugar, and the mineral salts of milk, that it is what it is. In milk of average chemical composition, there are for every 100 parts of water 4 parts of albuminoids, 5·2 parts of milk-sugar, and ·85 parts of the mineral constituents; so that the proportion of the quantity of water on the one side, and the sum of the above-mentioned constituents, in addition to the fat, is in proportion of 100 to 10·1, or roughly 10 to 1. Taking the percentage of water in properly-prepared butter as on an average at 15 per cent, it must contain on this account ·6 per cent of protein, ·8 per cent of milk-sugar, and ·13 per cent of mineral salts. In the process of thorough washing or salting with 4 per cent of salt, and after powerfully working it, the quantity of protein matter, and even to a greater extent also the milk-sugar or the lactic acid in the butter, is diminished.

When properly manufactured, the raw butter from the churn, after being passed through a hair sieve and before being worked, contains about 16 to 22 per cent of water, and between 76 and 82 per cent of fat. In the preserved butter of commerce the quantity of the individual constituents very rarely exceeds the limits of the *following percentages:—*

Limits for the percentage of water, ...	7 to 16	per cent.
,, ,, fat, ...	80 to 91	,,
Other organic constituents, ...	·8 to 2	,,
Limits for the percentage of ash (not including the salt added), ...	·1 to ·28	,,

The best kinds of butter contain not less than 82 per cent of fat, not more than 15 per cent of water, and not more than 2 per cent of the other constituents, exclusive of the added salt.

Pure butter is a bad nourishing medium for micro-organisms. The more nitrogenous matter the butter contains, the more favourable is it for the growth of bacteria and moulds in and on the butter. The keeping qualities of butter especially are in danger, if decomposition bacteria have developed, during souring, in the liquid churned, and infect the butter.

The average chemical composition of the finished article is indicated by the following analyses:—

	From Sweet Cream and without Salting.		From Sour Liquid Salted.	
	Unwashed.	Washed.	Unwashed.	Washed.
Water, ...	15·00	15·00	12·00	12·50
Fat, ...	83·47	83·73	84·75	84·62
Protein matter, ...	0·60	0·55	0·50	0·48
Other organic matter, ...	0·80	0·60	0·55	0·40
Ash or ash and salt, ...	0·13	0·12	2·20	2·00
	100·00	100·00	100·00	100·00

The specific gravity at 15° C. is, on an average, ·9437 for unsalted butter, and ·9515 for salted butter. The melting and solidifying point of butter are approximately the same as those which were given in § 6 for pure butter fat.

As an example of the chemical composition of the pure ash of butter, the following results give the composition of the ash of unsalted, unwashed, and well-worked butter made from sour cream:—

Potassium oxide, ...	19·329
Sodium oxide, ...	7·714
Calcium oxide, ...	23·092
Magnesium oxide, ...	3·287
Phosphoric anhydride, ...	44·273
Chlorine, ...	2·604
Iron, sulphuric acid, and loss, ...	0·288
	100·587
Deduct oxygen replaced by chlorine, ...	0·587
	100·000

The quantity of phosphoric acid quoted above includes that formed by the burning of the phosphorized lecithin.

106. The Investigation and Testing of Butter.—Ordinary chemical analysis of butter offers no special difficulty. If butter is to be tested for adulterants, the methods used in determining its chemical composition are for the most part not available. The processes used for this purpose are of a special kind. In such a test of butter, what is sought for is the presence of (1) deleterious colouring matters; (2) preservatives; (3) unusual quantities of water, or of foreign solid bodies which have been added to the butter for the sake of increasing its weight; and (4) foreign fats. The substances mentioned under Nos. 1, 2, and 3 demand difficult and complicated methods of investigation, so that they can only be carried out by a chemical specialist. On the other hand, it is easy to detect adulteration of butter with water, which is the most common of the above-mentioned adulterants. This method of adulteration is easily effected by melting unsalted butter in hot water, and by stirring up the fat with the water; or by working unsalted butter in salt water, or working salted butter with fresh water. The weight of the butter can be increased by this action to the extent of 26 per cent. Owing to the wide extension of the trade in margarine, and its use as an article of consumption, as well as the custom of selling margarine as butter, the investigation of butter for foreign fat, or the difference between butter and other fats, is especially important. The most valuable methods of research used for this purpose, are based upon the fact that butter-fat contains a number of neutral fats, with volatile easily-soluble fatty acids, forming on an average about 8 to 9 per cent of its weight, which in other fats are either

entirely absent, or are only partly present and in very small quantities. The proportion of the quantity of volatile to the non-volatile fatty acids found in the fat tested is correspondingly determined by one or other of the methods. If this proportion were invariable in butter-fat, it would be possible to detect the smallest possible quantities of foreign fats in butter. Since, however, it varies within comparatively wide limits, the case with regard to the testing of butter is almost the same as with regard to the testing of milk. Adulteration in small quantities is as difficult to detect in this case as in the former. No doubt, under very special unfavourable circumstances, such as very rarely occur, butter may contain 20 to 25 per cent of margarine adulteration, and the adulteration cannot be proved by investigation. On this account, in addition to the determination of the quantity of volatile or non-volatile fatty acids, a number of other tests for butter-fat have been applied. Thus, for example, there is the determination of the specific gravity of the fat at the boiling temperature of water with a margarimeter, since it has been observed that most of the different kinds of fat show a lower specific gravity than butter-fat. This method of testing is, however, only valuable in the cases in which the margarimeter shows a lower specific gravity in the fat investigated than that of butter-fat, since various vegetable fats, such as earth-nut oil, sesame oil, and poppy oil, have the same, or even a higher, specific gravity, than pure butter-fat. It has further been recommended to determine the coefficient of the fracture of the fat at a certain temperature, by means of a refractometer, since it has been found that pure butter-fat has a less high fracture coefficient than most of the other kinds of fat. The fat should also be tested in polarized light by means of a 75 linear enlargement, owing to the fact that the fat from melted margarine, on cooling, assumes a kind of crystalline structure, and exhibits characteristics in polarization, which butter-fat does not show, even although it has not been somewhat equally melted and again cooled. It is not possible to refer to the many different proposals for the detection of adulteration which have been made in addition to those above-mentioned.

In the testing of butter for the detection of substances which are not fat, the centrifugal butter-tester of Lefeldt is useful, as it renders the investigation easier, and points quickly to the discovery of suspicious butter. *Up till about 1870, it was not possible to distinguish butter-fat*

with certainty from animal-fat. The discovery of the Hehner method rendered this possible. In this method, the fat to be tested, after being prepared in a pure solution, is saponified, the soap thus obtained is decomposed, the soluble and insoluble acids separated, and the total weight of the palmitic, stearic, and oleic acids estimated. The sum of these three insoluble fatty acids varies in pure butter-fat from 85·5 to 89·8 per cent, and rarely exceeds in all the rest of the fats 95·5 of the total fat investigated. A simple and much-used method, based upon a similar principle as the Hehner, is the Reichert. It was first somewhat changed by Meiszl and subsequently perfected by Woolny. The Koettstorfer method has also proved itself very useful. This method recommends the determination of the capacity for saturation of the acids in the fat investigated, by the number of milligrammes of potassium hydrate required for saponifying 1 gram of fat. This saturation equivalent varies for pure butter-fat, according to the experiments that have been performed so far, between 221 and 233·4 milligrammes of potassium hydrate. The other fats and oils show a lower saturation equivalent, generally from 197 to 178 milligrammes of potassium hydrate.

If butter has to be tested for the detection of foreign fats, a definite opinion may be formed by determining, first, the sum of the insoluble fatty acids by the Hehner method; secondly, the relative percentage of volatile fatty acids by the Reichert-Meiszl-Woolny method; thirdly, the refraction coefficient at 22° C.; fourthly, the specific gravity of the fat at the boiling temperature of water; and fifthly, perhaps also by the Koettstorfer method. The number of c.c. of a tenth normal alkaline solution required for 5 grams of butter-fat in carrying out the Reichert-Meiszl-Woolny method varies, in most cases, between 21 and 33, and the specific gravity of pure butter-fat lies between ·8650 and ·8685 at 100° C. The determination of the so-called iodine coefficient is, owing to the great variation which it may exhibit, not well suited for the detection of foreign fats in butter. The complete analysis of butter can be carried out as follows:—

(1) *Determination of Water.*—5 to 10 grams of butter are weighed in a small glass capsule, lightly covered, and are then allowed to melt on the air-bath. The melted fat, after it has become clarified, is filtered in the air-bath on to a weighed filter into a little weighed capsule, care being observed in pouring it out that all the fat and nothing of the watery mass lying beneath the fat is poured on to the filter. The watery residue in the glass beaker is then dried at 100° C., and is left along with the fat in the capsule and on the filter, which should remain, if possible, standing in a dry shelf, cooled in the desiccator, and weighed. This is repeated until the weight obtained by two subsequent weighings shows at most a milli-

gramme of difference. From the loss of weight thus found—the weight of the glass beaker is ascertained by weighing the butter,—the percentage of water in the butter is calculated.

(2) *Determination of the Fat.*—The residue in the beaker is dissolved and detached with a small glass stirrer as perfectly as possible from the bottom of the beaker, washed out with pure ether, free from water, on to a filter, which is fastened in a small funnel over the beaker containing the chief quantity of the fat; the glass beaker and the stirrer are then washed with ether, and the filter and its contents are washed with ether till a few drops of the filtrant show no trace of fat when evaporated on a watch-glass. The ether is then evaporated off, and the filter is dried in an air-bath at 100°, cooled in the desiccator, again placed in the air-bath, and after cooling weighed. This is repeated till the weight is constant.

(3) *Determination of the Ash.*—The residue remaining on the filter is charred along with the filter-paper at a low heat, and after it has been repeatedly boiled with distilled water and filtered it is burned to a white heat. The filtrate is then added in small quantities to the ash in the platinum capsule, placed in the water-bath to dry, and finally is burned along with the filter, with a cover at a moderate heat, allowed to cool, and weighed, the weight of the ash from the two filters being deducted. Since fresh butter contains for the most part very little over ·1 per cent of ash, the percentage of chlorine will only be about ·003 per cent, and in this way it is easy to arrive at a closely approximate estimation of the percentage of salt in salt butter by a determination of the chlorine in the ash.

(4) *Determination of Proteids.*—80 to 100 grams of butter are weighed. The fat, after being perfectly separated from water, is separated from the remaining butter constituents, and is exactly determined in the method described in (1) and (2), descriptive of the water and fat determinations. The residue remaining on the filter-paper is then used for the determination of the nitrogen. The proteids are obtained by multiplying the percentage of nitrogen found by the factor, 6·39. As it is doubtful, especially in the case of old butter and that made from sour cream, whether all the nitrogenous substance belongs to the albuminoid group, the number denoting the proteids may be regarded as a little inexact.

(5) *Determination of the Non-nitrogenous Soluble Organic Bodies (Milk-sugar, Lactic Acid, &c.).*—If the percentage of water, fat, ash, and proteids have been determined exactly by two duplicate analyses, showing close agreement, the sum of the weight of these constituents is deducted from 100, the difference being credited as milk-sugar, lactic acid, &c., or non-nitrogenous soluble organic bodies. The attempt to determine this group of substances

directly has been in my experience unsuccessful, as in washing the fat free residue with water, sometimes more, sometimes less, of the nitrogenous bodies is apt to be found in the solution. Naturally the uncertainty which belongs to the number denoting the quantity of protein bodies will influence the number calculated by difference, which represents the quantity of non-nitrogenous soluble organic bodies.

If butter has to be tested for its percentage of preservatives, with the exception of salt, or for the determination of foreign solids which have been added for the purpose of increasing its weight, the following process may be adopted if it be not desired to detect the presence of foreign fats.

10 to 40 grams of the butter to be tested are melted in double or three times the quantity of warm distilled water, a little alcohol is then added, and the mass is stirred very slowly for about fifteen minutes at a temperature just above the melting point of fat. It is then allowed to stand still for some time, and the liquid lying below the fat, as well as the residue, is submitted to chemical and microscopical investigation. Since it is unnecessary to add to the special precautions to be taken in detecting different substances, and since adulteration of butter with potato meal, gypsum, water, glass, &c., only occurs very rarely, there is no necessity to describe the methods for the detection of all possible and impossible adulterants. If the butter be not adulterated, the liquid below the fat becomes clear, or almost perfectly so, when it is warmed with soda lye, added in slight excess.

For the detection of the usual colouring agents, Hilger recommends the following process:—About one-half of the liquid which has been filtered from the sediment lying at the bottom under the fat, and which has been obtained by the method above described, is evaporated down to a fourth part of its volume, and is then divided into three like portions, *a*, *b*, and *c*. Portion (*a*) is decomposed with hydrochloric acid. If this be followed by a yellow coloration it indicates the presence of binitrocresol or binitronaphthol. Portion (*b*) is decomposed with ammonia for the detection of any turmeric colouring matter. Portion (*c*) is finally heated with some sugar and hydrochloric acid. The appearance of a red colour points to the presence of saffron. The remaining half of the original solution is evaporated to dryness, and the residue treated with concentrated sulphuric acid. If annatto be present a blue colour is produced. For the detection of colours derived from carrots or marigolds no reliable tests are known. Genuine saffron should not colour petroleum ether, as has been asserted.

The method for the determination of foreign fat in the butter has been already described.

CHAPTER V.

CHEESE AND CHEESE-MAKING.

107. The Coagulation of Milk and the Properties of the Coagulum.—The object of the manufacture of cheese is the utilization of the caseous matter of milk. This is effected by coagulating the milk, by precipitating the caseous matter in it by suitable reagents, and by making the coagulated material, which represents the raw cheesy matter, and which encloses all the remaining constituents of the milk in varying quantities, into cheese, and by ripening fresh cheese in order to render it suitable for consumption. From a very remote period, it has been the custom to separate the solids of milk by allowing it to sour spontaneously, or by treating it with rennet. The coagulum obtained by spontaneous souring and that obtained by the use of rennet were formerly regarded as identical. In the years 1870 to 1875, through the labours of Schmidt and Kapeller, and more especially through the accurate researches of Hammarsten, which have been already described in § 5, it was proved that the coagulums respectively obtained by these two different methods differed from one another. The chemical difference consists in the fact that the coagulum obtained by souring contains nothing but casein, whereas that obtained by rennet contains paracasein, a decomposition product of casein. For that reason a distinction must be made between sour-milk cheese and rennet cheese, and this all the more because both kinds of coagulum have been proved to manifest many other very important differences in their properties. For the sake of simplicity we will call the acid precipitate *curd*, and the rennet precipitate *coagulum* or raw cheese. As far as the manufacture of cheese is concerned, the latter is more important and valuable than the former.

The fresh coagulum obtained at a temperature of 30° to 35° C. is an elastic substance, scarcely soluble in water, and not in the slightest degree sticky or greasy. When properly prepared, it contains a large number of different kinds of spores, but no luxuriantly growing vegetative forms of bacteria or fission spores. It is admirably suited for the manufacture of a large number of different kinds of

cheese. It forms, to a certain extent, a rich medium for suitable development, as desired, of the different kinds of micro-organisms present. These organisms can be developed or suppressed, and the growth of other kinds favoured. The most valued and the most lasting kinds of cheeses are prepared from the coagulum.

The curd is not elastic, is less insoluble in water than the coagulum, and is sticky and greasy. Since, in accordance with the method by which it is obtained, it possesses a strong acid reaction, and contains luxuriantly growing lactic bacteria, it only forms a suitable nutritive medium for a comparatively limited number of bacteria and fission fungi, and offers, therefore, a much more restricted basis for the manufacture of cheeses of different kinds. In sour-milk cheeses, with few exceptions, the process of ripening resembles in general the putrefactive process, and goes on from outside to inside. In the case of the different rennet cheeses, on the other hand, the process of ripening is essentially characterized as a process of decomposition, or a process of fermentation, which goes on throughout the whole mass with different phenomena, and appears as a highly complicated process, in which, in addition to bacteria, moulds, and perhaps also fission fungi, take part.

Coagulum and curd are distinguished from one another by the fact that the former encloses the entire quantity of di- and tri-calcic phosphates which are in suspension in the milk, while the latter (the curd) only encloses a small quantity of calcic phosphate, since a large portion of the suspended phosphate is dissolved by the lactic acid which the separation of the curd gives rise to, and is, therefore, not mechanically enclosed in the precipitate of the coagulation.

The process of milk coagulation by means of acids may be simply explained as follows:—As has been pointed out in § 5, the caseous matter of the milk may be regarded as a chemical compound of casein or an albuminoid (which plays the part of an acid), along with calcium oxide, in the proportion of 100 parts of casein to 1·55 parts of calcium oxide. From this compound of casein with lime, which is present in the milk as a strongly coagulated colloidal mass, casein is separated, by the addition of acids, in an insoluble from, *i.e.* in the form of a non-precipitable body. This operation takes place in the souring of milk by acids.

The rennet souring of milk does not admit of such simple explanation. We know, it is true, a good deal regarding the accompanying conditions under which it takes place, but with regard to the process itself little is known. We know little more with certainty than that it is a process of

fermentation, and that it is directly caused by ferments. Hammarsten has carried out the most elaborate and trustworthy researches on this subject. If we take a solution of caseous matter prepared according to his directions, and precipitate or coagulate it with rennet, and then perfectly separate the whey, obtained by steaming and the careful addition of acetic acid, from the small quantity of rennet coagulum which is still present, and then filter from the filtrate, we can separate out by means of alcohol, tannic acid, or Millon's reagent, a protein body, which, in its chemical behaviour, differs essentially from albumin and casein, and which is also free from bodies of the nuclein type. Hammarsten names this body whey-protein, and suggests with regard to the nature of rennet coagulation the following theory:—The rennet ferment acts, within certain definite temperatures, directly on the casein, and decomposes it, by means of hydration, into two new albuminoids, in which the one, the whey-protein, remains in solution, but the other, in the event of soluble lime salts being present, is precipitated as a coagulum. Schulze, of Zürich, suggests that the albuminoid bodies which Hammarsten designates by the term cheese, a term which admits of different meanings, should rather be designated by the term paracasein. Söldner has shown that Hammarsten's statement, that the rennet coagulation only takes place in the presence of dissolved calcium phosphate, is so far incorrect, and it has been already shown that it does not depend on the presence of soluble calcium phosphate, but chiefly on the presence of soluble lime salts.

According to Hammarsten's own researches, or those carried out under his supervision, casein, paracasein, aud whey-protein have been shown to contain the following quantities of carbon, oxygen, and nitrogen:—

	Casein.	Paracasein.	Whey-protein
Carbon, ...	52·96	52·88	50·33
Oxygen, ...	7·05	7·00	7·00
Nitrogen, ...	15·65	15·84	13·25

As has already been mentioned, rennet coagulation has to be regarded as a fermentation process. Fermentation processes are chemical processes of a particular nature, in which organic bodies are decomposed into simpler compounds by union with water. The characteristic of fermentation processes consists in the fact that they can be induced by a particular fermentation starter, an unorganized or organized ferment, and that for this purpose a comparatively small quantity of ferment suffices; but the ferment does not enter into a stable chemical combination either with the fermentable body, or with the decomposition products formed. The progress of all processes of fermentation is influenced to a large extent by the ferment, by the percentage of water in the fermenting mass, and by the temperature

The action of unorganized, or chemical or soluble (hydrolytic) ferments, is believed to take place in such a way that a molecule of the ferment unites with a molecule of the transformed body, and forms a compound which is immediately decomposed by water again. The molecule of the ferment separates out unchanged, and bodies are formed which owe their origin to the hydration of the body undergoing fermentation. It may be supposed that the budding fungi and bacteria act indirectly in exactly the same manner, if it be assumed that they possess the capacity to separate out under certain conditions unorganized ferments or enzymes.

108. Rennet and its Properties.—By the term "rennet" in dairying, is understood the liquid or powdered preparations, suited for purposes of cheese manufacture, which contain as their chief constituent that characteristic rennet ferment which exerts an extraordinarily powerful action on the caseous matter of the milk. This ferment is found in the stomach of a large number of animals, and also in the human stomach. It is especially abundant in the stomach of young mammals while they are still suckling; and is a secretion of the rennet-glands, which are embedded in the lining of the stomach. For the preparation of rennet, calves' stomachs are almost exclusively used, on account of the ease with which they are procured. Up till now it has not been possible to obtain the rennet ferment in a pure condition. From an extract, obtained by treating the dry stomach of a calf with a 5-per-cent salt solution, and then by increasing the percentage of salt to 10 per cent, Soldner obtained a precipitate which, when dried, formed a gray-brown powder. One part of this powder was sufficient to coagulate at 35° C., in 40 minutes, one million parts of milk. As the powder contained 36 per cent of organic matter, one part of this was sufficient, therefore, under the above conditions, to effect the coagulation of 2·8 million parts of milk. Further, as the organic substance did not consist of pure rennet, the ferment must therefore exert a much stronger action on milk. The rennet ferment belongs to the unorganized class of ferments, and more particularly to those which are able to decompose albuminoids. Its action is connected with well-defined conditions, which can be accurately and shortly described. Its action does not take place at all if the milk lack soluble lime salts, and if the milk possess an alkaline reaction, however faint. Milk which colours, or which reddens phenol-pthalein perceptibly, is not coagulated by rennet. An acid reaction, within certain narrow limits, assists the action of

rennet. When, however, free acid develops in the milk, which is able to attack the caseous matter, the coagulation which is formed no longer exhibits those properties which belong to a coagulation *exclusively formed by rennet. It is worthy of note that the* reaction of milk is not altered to the slightest extent by the action of rennet. The action of the rennet ferment is largely influenced by the temperature and by heat.

By boiling, or by the addition of an alkali, milk loses the power, either entirely or partially, of being precipitated by rennet. In milk which has been heated for a long time, or in milk which has been boiled, after the addition of rennet, a precipitate is formed, it is true, but it consists of a coagulum which is highly flocculent, and never forms a firm united mass. The reason of this, as Soldner has shown, is due chiefly to the fact that in this action a precipitation of calcium phosphate is effected, which causes the entire removal or diminution of the soluble lime salts. Probably other changes unfavourable to the action of rennet may also take place *in the milk. Milk which has been boiled, or to which an alkali has* been added, and which has thus lost, either entirely or partially, its susceptibility to the action of rennet, regains this susceptibility if it be treated with calcium chloride or other soluble lime salt, or if a small portion of the precipitated lime salts be dissolved again by the addition of carbonic acid or dilute acid. If fresh milk be not coagulated by the action of rennet—a fact which has been very rarely noticed,—this may be accounted for by some disturbance in the milk-gland, through which the milk exhibits a slightly alkaline reaction, and does not contain soluble lime salts.

Fresh milk of ordinary quality exhibits to litmus colouring matter an amphoteric—that is, a faintly alkaline, and, at the same time, a faintly acid reaction. The degree of acidity caused by the presence of acid phosphates, which varies within narrow limits, may be easily determined by titration. This is carried out, according to the directions of Soxhlet and Henkel, as follows:—50 c.c. of milk is titrated after the addition of 2 c.c. of a 2-per-cent phenol-pthalein solution and $\frac{1}{4}$ normal soda solution. The end *of the reaction is denoted by the formation of a faint red colour in* the fluid. The number of c.c. used, when calculated on 100 c.c. of milk, represents the measure of the acidity of the milk. This, as a rule, amounts to 7. The greater the acidity of the milk, the more powerful is the action of rennet when the conditions are otherwise similar. By the addition of $\frac{1}{4}$ normal soda solution, or $\frac{1}{4}$ normal hydrochloric acid solution, we can impart to the milk at any time a quite definite acidity. In using the numbers denoting the acidity of milk, found by Soxhlet and Henkel, it

must be assumed that we are dealing with milk which has not been diluted with water. By the addition of water to milk its acidity is diminished, owing to the fact that the calcium phosphate, with alkaline reaction, is carried into solution.

The strength of the action of the rennet increases with increasing temperatures, at first slowly, then always more quickly, and reaches its maximum at 41° C., and rapidly decreases from that point with increase of temperature. It has further been established that the rennet coagulum at 15° C. is flocculent and spongy, at 25° to 45° C. it is more or less firm, resembling porcelain, and at 50° C. it is again loose and spongy and jelly-like. Solutions of rennet become permanently inactive if heated to a temperature of over 60° C. If they be kept for some time at a comparatively high temperature, but below 60° C., they lose their strength. A solution of rennet which acted upon milk (fresh) in the proportion of 1 to 3750, and which, to effect sterilization, was heated for 32 hours at 59° to 60° C., and which during that time was maintained at a neutral reaction, lost in the above treatment 44 per cent of its original strength. According to experiments carried out in my laboratory by Dr. F. Baumann, solutions of rennet of neutral reaction cannot be sterilized at temperatures over 60° C., without at the same time becoming inactive. With regard to the relations of temperature to rennet action between 20° and 50° C., the following numbers may be quoted. The table gives the quantities of milk coagulated at different temperatures between 20° and 50° C. by equal amounts of rennet, taken from the same preparation of rennet ferment, in equal periods of time. Taking the quantity of milk coagulated at 41° C. as 100, the following are the results:—

20°	... 18	36°	... 89	44°	... 93
25	... 44	37	... 92	45	... 89
30	... 71	38	... 94	46	... 84
31	... 74	39	... 96	47	... 78
32	... 77	40	... 98	48	... 70
33	... 80	41	... 100	49	... 60
34	... 83	42	... 98	50	... 50
35	... 86	43	... 96		

The limits of temperatures between which, in actual practice in cheese-making, milk is coagulated with rennet, are 20° and 48° C. As a rule, the most commonly applied temperature is between 30° and 35° C

Watered milk coagulates more slowly than pure milk, and by the addition of a large quantity of water, milk can be deprived of the power to form a firm coagulum on the addition of rennet. If solutions of rennet be submitted for some time to the action of light, they gradually decrease

in strength. The following facts and directions may be stated with regard to the action of rennet:—

(1) The time of coagulation under like conditions of temperature, and strength and amount of rennet used, is directly proportional to the quantity of milk to be coagulated.

(2) The time of coagulation is, under similar conditions of temperature and equal quantities of milk, inversely proportional to the strength or the quantity of rennet used.

(3) The strength of rennet is, under like conditions of temperature and time of coagulation, directly proportional to the quantity of milk acted upon.

On the basis of the last of these dicta, the custom of determining the strength of the different kinds of rennet has been founded. These conditions can only be regarded as holding true at temperatures between 30° and 40° C., and in such cases where the quantity of rennet used for coagulation is not more than will effect coagulation in from five to ten minutes. If the quantity of rennet be increased, and the quantity of milk remain the same, the time of coagulation does not increase in the same proportion as in (2) but more quickly with the increase in the quantity of rennet.

Formerly only solutions of rennet were used in practice. These solutions were either made in the cheese factory daily for immediate use, or were kept in very small stocks. At present, in Germany, solutions of rennet are manufactured on a large scale for sale, and these are almost exclusively used. Rennet is also sold in the form of a powder. The introduction of this practice dates from about 1870, when it was introduced by the apothecary Krick of Bar-le-Duc, in France, and by Dr. Christian Hansen in Copenhagen, and soon also by others.

At first the solutions were only in limited demand. They were very dear, and were far from satisfactory. It was only after Soxhlet had given definite instructions, based on extensive investigations, with regard to the most economical and useful application of strong rennet solutions, that commercial rennet was improved in quality and reduced in price, and gradually in the course of time found its way into more general use.

The strength of the rennet preparation is best measured by estimating how many cubic centimetres of a milk of ascertained acidity, for example of an acidity of 7, are coagulated by one cubic centimetre of rennet solution or 1 gram of rennet powder at a

temperature of 35° C., in 40 minutes. This is best carried out as follows:—5 c.c. of the rennet solution which it is desired to test, or a watery solution in which 5 grams of the rennet powder is dissolved, are made up to 100 c.c. with distilled water. After thorough mixing, 10 c.c.—representing ·5 c.c. or ·5 of a gram of the rennet preparation—is drawn off with a pipette and added to 500 c.c. of milk possessing an acidity of 7, which is then heated to exactly 35° C. The exact time to a second is noted when this takes place. The solution of rennet is blown with considerable force from the pipette into the milk, in order that it may be uniformly distributed throughout the mass, which is quickly submitted to a rotatory motion. As is obvious, there will be one part of rennet for every 1000 parts of milk, that is, 1 c.c. or 1 gram of rennet per 1000 c.c. of milk. The thermometer, which has been already placed in the milk, is then gently moved to and fro, and the time noted which elapses till coagulation becomes apparent, that is, till fine particles of coagulated milk are apparent behind the thermometer as it is moved as carefully as possible. The temperature of the milk must be maintained during the whole operation as nearly as possible at 35° C. If, for example, the coagulation period has been observed to last 5·55 minutes, then the quantity of milk (x) which would be coagulated at the same temperature by a similar quantity of rennet in 40 minutes' time is as follows:—

$$5{\cdot}5 : 40 :: 1000 : x = 7207.$$

The rennet preparation is thus found to possess a strength of 1 : 7207, or, roughly speaking, 1 : 7200.

The commercial solutions contain, in addition to rennet ferment, small quantities of pepsin, a non-organized ferment which produces lactic acid, comparatively large quantities of slimy matters, and other organic substances, the composition of which is little known. They contain salt or alcohol, and often also other preservatives, such as boracic acid, glycerin, ethereal oils, thymol, salicylic acid, benzoic acid, &c. All these substances increase the keeping property of the rennet solutions at the expense of their strength, since they render a portion of the rennet ferment inactive.

Rennet powders, on account of the method of their preparation, are richer in the ferment and poorer in pure organic substances than the pure commercial solutions of rennet. They are obtained, as a rule, by separating and drying the precipitate prepared by

suitable methods from the rennet solutions, and are rich in rennet ferments.

A commercial solution of rennet should possess an inviting appearance, should be clear, and should neither possess a disagreeable nor a strongly aromatic smell. They must possess keeping properties, and should not lose in the course of a year more than 25 per cent of their strength. They should not be too weak, and if kept for several months protected from the light, they should possess a strength of 1 to 6000; and, finally, they ought not to be too dear. A litre of a good rennet solution, possessing a strength of from 1 to 10,000 to 1 to 6000, should not cost more than two to three marks.

A good commercial rennet powder should have an appearance almost entirely white, should possess practically no smell, and on being dissolved in water should leave only a very small residue. It should obviously not contain lead, a body which has been found in considerable quantities in some samples. As rennet powder is richer in the amount of ferment it contains, and poorer in foreign constituents than the commercial rennet solutions, it possesses an advantage over the solution. Up till now, however, the use of the powder in practice has been less popular than the use of the more convenient commercial rennet solutions, since there are different and not altogether unimportant inconveniences attached to its use. Rennet powder must be carefully protected, for example, from damp, since if it become moist it decomposes and putrefies. Further, before its use it must be perfectly dissolved for fifteen minutes in water or sweet whey. If the milk be treated with the solution before the powder is perfectly dissolved the curd will not be uniform. There are rennet powders in commerce which possess a strength of 1 to 300,000 or even greater. In addition to rennet powders, rennet preservers are also sold in the form of tablets.

The juices of certain plants, for example, the fig-tree (*Ficus Carica*), artichoke (*Cynara scolimus*), some kinds of thistle (for example, the *Carlina corymbosa* and *C. acaulis*), the melon-tree (*Carica Papaya*), withanie (*Punceria coagulans*), the butter-wort (*Pinguicula vulgaris* and *P. alpina*), exert on milk a similar action to that of rennet. The juices of the fig-tree and of some thistles are the only ones of these which in rare cases have been tried in practice. The special rennet used by the Israelites was not prepared from plants, but from the stomachs of calves killed according to the Jewish law.

As mentioned, the rennet required was formerly prepared in the cheese factory itself. In such cases it was made from dried calves' stomachs, which had been allowed to stand for some hours, partly in pure water and partly in water which had been rendered sour with acid whey, citric acid, or wine vinegar, at a temperature of from 20° to 35° C. Occasionally, in order to preserve them, there was added to such preparations, if they were made on a large scale, salt, spirits of wine, pepper, saltpetre, aromatic herbs, nutmeg blossom, cinnamon blossom, laurel leaves, ethereal oils, and such like. Under certain circumstances, calves' stomachs, which were specially preserved and kept in the form of balls, or packed in stone jars, were utilized for the preparation of the necessary rennet solutions. These were obtained as follows:—The calves' stomachs dried in the air were first of all thoroughly separated from the fat, then finely minced, and treated with 5 per cent of salt and pepper. The mass was then dipped in vinegar, made into a ball, and after lying for eight to twelve hours, was mixed with a quantity of butter-milk sufficient to make it into a paste, and to admit of its being conveniently made into balls as large as the fist. These balls were left for from three to four weeks in a moderately warm, dry place, slightly smoked, and then kept for use.

Soxhlet's prescription for the preparation of good keeping rennet solutions is as follows:—

The fresh stomach is emptied, blown up quickly, dried in the air, and kept for at least three months. After the portion devoid of folds has been removed, it is cut into pieces about a square centimetre in size; for every 100 grams of stomach 1 litre of water, 50 grams of salt, and 40 grams of boracic acid are taken. It is then left to stand at the ordinary temperature of the room for five days, with frequent shaking. To every litre of water used, 50 grams of salt are added, and the solution is then filtered. For 1 litre of water there should be obtained 800 c.c. of filtrate, which should be made up to a litre by the addition of 200 c.c. of a 10-per-cent salt solution saturated with boracic acid. Such rennet possesses a strength of about 1 to 10,000, and that after lying for two months. Per litre it costs as follows:—

From 3 to 3·5 calves' stomachs at 20 pfennig,	*60 to 70 pfennig.*
50 grams of boracic acid at 2 marks per kilo.,	10 "
Salt and filter-paper,	5 "
Total,	75 to 85 pfennig.

Instead of boracic acid, alcohol may be used, but the rennet solution obtained possesses poor keeping properties. 100 grams of calves' stomach

are treated with 1 litre of water and 50 grams of salt. After five days 50 grams of salt are dissolved in the liquid, and from 100 to 110 c.c. of 90-per-cent alcohol are added. The liquid is then filtered. The filtrate thus obtained contains per litre 100 grams of the calves' stomach, 10 per cent of salt, and 8 to 9 per cent by volume of alcohol. Fresh rennet solutions prepared in this way lose about 30 per cent of their strength during the first two months, but from that time remain for the next eight months and longer almost quite constant in their strength. On this account, rennet solutions should only be introduced to the markets, and sold, after they are two months old.

According to Dr. Schmoger, samples of rennet powder of the following brands gave the following results:—

	Blumenthal's Rennet Powder.	Blumenthal's Extract.	Hansen.
Water, ...	0·87	85·49	78·86
Nitrogenous organic matter, ...	1·06	0·19	2·00
Non-nitrogenous organic matter,	2·06	0·84	0·24
Ash, ...	96·01	13·48	18·90
	100·00	100·00	100·00

The ash of each of these three kinds of rennet consisted essentially of salt, and exhibited only a weak boracic-acid reaction.

109. The Application of Rennet in Practice.—The rennet serves to coagulate milk in a very short period of time, and to obtain from it the coagulum which forms the raw material in the preparation of cheese. A too quick coagulation of milk does not favour the further treatment of the coagulum for conversion into cheese. The period of coagulation in the preparation of most kinds of cheese varies from 15 and 90 to 120 minutes. In the preparation of the majority of cheeses, however, it does not last for more than 40 minutes. Observations show that the coagulum is not immediately formed after the addition of rennet, the physical condition of the milk being changed quite slowly. It first of all gradually becomes viscous or syrupy, then gelatinous, and finally so firm that when the finger is dipped into it and then slowly drawn out again, the coagulated matter gradually breaks. The action of the rennet, however, does not cease with the lapse of the coagulation period. The coagulum becomes firmer, and poorer in water, until, in a longer or shorter period, it reaches as great a degree of firmness as it can possibly attain under existing circumstances. During the subsequent thickening, a green yellow-coloured whey is formed, which increases

the firmer the coagulum becomes. The firmness of the coagulum depends, in the first instance, on the strength of the rennet used, on the length of the coagulation period, and on the temperature during coagulation. The percentage of water in the coagulum is in inverse proportion to its firmness. Experience has shown that the coagulum, of each of the many different kinds of rennet cheeses, requires a certain definite percentage of water, and a certain definite firmness. Since these two things are unalterably determined by the nature and method in which the separation of the milk is effected, and since that depends on slight delicate differences, the coagulation of milk by means of rennet demands the greatest attention and care. This is all the more the case, as the firmness and the percentage of water of the coagulum is not merely dependent on the period of coagulation, and the temperature and the quantity of rennet used, but is also dependent on the percentage of the fat, and the acidity of the milk. In the manufacture of very soft cheeses, the milk is separated at a temperature of from 20° to 28° C., and the period of coagulation is at the same time lengthened. On the other hand, if hard-keeping cheeses, suitable for keeping for a long time, are to be prepared, the coagulation is effected at from 28° to 35° C., and its duration is shortened. If coagulation take place very slowly, that is to say, if it occupy about an hour or more, certain dangers arise which have to be watched, and subsequently, if possible, have to be guarded against. The longer the coagulation period the more difficult it is to keep the milk during the whole time at an equable temperature. In the case of the manufacture of cheese from whole-milk, this difficulty manifests itself in the collection of the fat in the surface layers of the coagulum. Too short a coagulation period can also give rise to undesirable results. The coagulum, when formed too quickly, may become so firm that it is impossible to work it in mass, and to break it up as finely as is necessary. In the manufacture of the same kind of cheese, it is necessary, in winter, to raise the coagulation temperature a little above that maintained on an average. This is also necessary in the case of milk which contains more than the average percentage of fat, or which is relatively less acid.

The object of all operations in the separation of milk is to obtain a coagulum which is of a perfectly uniform nature. This has to be kept in view in practice before everything else in coagulating with rennet.

In the separation of milk, in addition to the necessary quantity of good rennet, and a good cheese-vat and suitable measuring vessels, a thermometer and a ladle for mixing the rennet with the milk will also be required. The following is the method:—After the milk has been brought by suitable heating and stirring to exactly the required temperature, the necessary amount of rennet is mixed into the milk. If it be intended to colour the coagulum of the cheese, the colouring matter ought also to be added in the exact proportion required, and should be thoroughly mixed with the milk. The milk is then allowed to rest in the cheese-vat covered with a lid, should it be necessary to maintain an equable temperature, and the liquid left to stand. The solution of rennet (rennet in the form of a powder must be dissolved before application) should form at least 1 per cent of the volume of the milk. The milk is tested from time to time, at first after considerable intervals, and subsequently oftener, in order to see if coagulation have taken place. Before proceeding further, the coagulum must be allowed to attain the desired degree of firmness. As soon as this is reached, it is ready for further treatment, in the cheese-vat, for the manufacture of cheese.

For taking the temperature during the process of coagulation, a thermometer fitted with a brass scale attached to a strong board, polished on all sides, is used. The necessary rennet is kept (when a rennet solution is used) protected from the action of light, and if a rennet powder be used it should be kept in a perfectly dry place.

If it be desired to test the rennet solution which is used, it can be done in the following manner:—The entire quantity of the milk is brought into the cheese vessel at the proper temperature. An empty dish, which will hold at least two litres, is placed in the milk at the beginning of the warming process, in such a way that it floats and assumes the temperature of the milk. In the meantime 10 c.c. of the rennet solution are measured out and diluted with water to 100 c.c. As soon as the mass in the vessel has reached the desired temperature, a litre of milk is poured into the dish, 10 c.c. of the diluted rennet solution is added and mixed, and the time which it takes to start coagulation is noted exactly to a second. If, for example, it has been observed that the milk in the bowl coagulates in 8·5 minutes, and if it be desired that the coagulation of the whole amount should last for about 40 minutes, all that is necessary is to divide 8·5 by 40 in order to find how many c.c. of rennet will be required for every litre of milk. Since 8·5 divided by 40 is ·2125, for every litre ·21 c.c. will be required approximately, or for every 100 litres 21 c.c.; and since a litre weighs approximately 2 lbs., for every 100 lbs., 10·5 c.c. of rennet will be required. It is possible at the same time to ascertain whether the coagulum possesses the proper condition, by making an exact test of the

coagulated mass in the bowl. Directly after the end of this operation, which can be done in less than 10 minutes, and if the temperature of the milk have not changed, the dish may be removed, and coagulation by the addition of rennet may be proceeded with. For example, if there be 657 lbs. of milk in the dish, $\frac{657 \times 10 \cdot 5}{100} = 68 \cdot 985$, or approximately 69 c.c. of rennet may be used, to which the necessary colour has been added. If the coagulation be not exactly concluded within the prescribed time, on account of the test in the dish not having been accurately carried out, the quantity of rennet used can be altered the next day so as to rectify the inaccuracy.

110. **The Colouring of Cheese.**—Nearly all the better kinds of rennet cheese, especially the finer kinds intended for export, are coloured when they are in the state of curd, and some Dutch, English, and American kinds are also externally coloured. Generally the curd is coloured of a very weak yellow or reddish-yellow tone, rarely is it coloured of a deep orange-yellow. The cheeses prepared in Switzerland and S. Germany are of a faint golden-yellow colour. The Dutch, English, and American cheeses are more or less of a reddish-yellow colour. For colouring cheese when in a state of curd, only liquid cheese-colouring substances are used, such as solutions of annatto colouring matter in an alcoholic soda solution, or alcoholic solutions of saffron. These are added to the milk at the same time as the rennet. The saffron solution imparts to the curd a gold-yellow colour, and the annatto solution a red-yellow colour.

Formerly milk was treated according to taste, for the purpose of colouring the curd, with commercial annatto paste or saffron powder. At present, in all cheese factories where work is carefully carried out, only commercial liquid cheese colours are used, a definite proportion of which is added to the milk. The preparation of good colouring solutions of annatto is so inconvenient that they should not be readily used in cheese-making. On the other hand, solutions of saffron are very simply obtained in the following way. For every gram of saffron, 20 c.c. of a mixture composed of equal parts of distilled water and common spirits of wine are added, and the saffron is dissolved in this mixture in a roomy bottle, corked, and allowed to stand for from four to five days at the ordinary temperature of the room, being frequently shaken and finally filtered through linen. If a pound of saffron cost 50 marks, and if for every pound of milk 2 c.c. of this extract be used, the cwt. of cheese will

cost about 24 pfennig to colour. The colouring of cheese in the curd is, therefore, by this method, cheaply effected, even if commercial colouring solutions are used, which are more expensive than the home-made ones.

111. Utensils Necessary in the Preparation of Cheese.—In the preparation of curd, special easily heated cheese vessels are used,

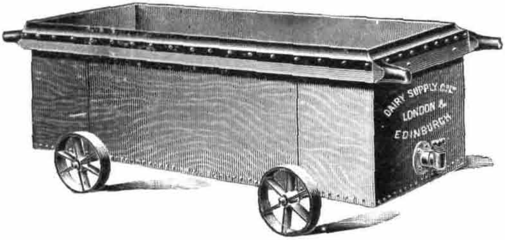


Fig. 57.—Cheese Vat for Steam.

which in different districts are differently shaped and made out of different kinds of material, and these are heated either over an open fire, or with steam or hot water. With regard to the crude and wasteful method in which milk is warmed in the cheese vessels by the simple introduction of steam (fig. 57), this has been entirely abandoned, even in the districts in which it was formerly practised.

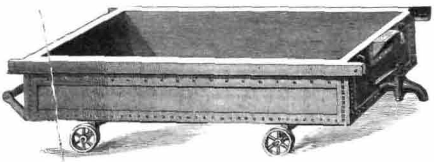


Fig. 58.—Cheese Vat for Hot Water.

The cheese vessels are generally round and boiler-shaped, or rectangular vat-shaped. On the continent of Europe, round vessels or cheese-tubs are almost entirely used, and in the large American and English cheese factories, in which the manufacture of cheese is conducted on a large scale, oblong cheese-vats are almost entirely used (fig. 58).

The cheese-tub (fig. 59) is best made out of the best bare copper, that is to say, copper not tinned. It should not be larger, or even as large, as to allow 1500 litres (328 gallons) of milk to be converted into cheese at once. Even in a vessel of this size it is difficult to

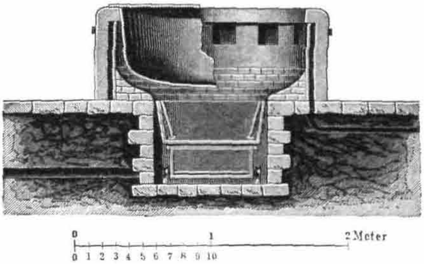


Fig. 59.—Fixed Cheese Kettle with Movable Firing (Perpendicula. Section).

obtain a curd perfectly uniform. Vats of a hemispherical shape are to be preferred to those of more strongly bulging or of conical shape, or that narrow towards the top. The cheese-vat is heated either over an open fire or with steam. In Switzerland, Upper Italy, Austria, and in S. Germany, heating over an open fire is still generally practised. The kettle is either hung on a movable bar over a closed, often even an open fireplace, or the kettle is built-in, and the fireplace is brought on a small iron rolling waggon which runs on a rail in a groove. The latter is better than the former. As, however, it is not possible, in heating a kettle over an open fire, to regulate the temperature of the milk and the curd as exactly and as reliably as it is in the case of a slow and regular steam-heating arrangement (fig. 60), this latter method is distinctly preferable. The unseemly Danish cheese jackets used for steam heating are certainly very impracticable. The copper kettles, the under part of which is

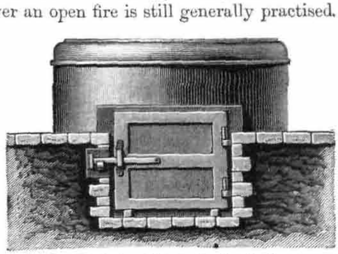


Fig. 60.—Fixed Cheese Kettle with Movable Firing.

double walled, and in which the steam is introduced into the hollow space between the walls, have also proved themselves unsuitable. The following method, which is characterized at once by its simplicity and cheapness, meets all requirements. A copper circular-shaped kettle with a projecting edge is placed in a common wooden vat. Steam is conducted through a tube which opens just above the bottom of the kettle. Opposite, a tube bent at its outward end and open at both ends is placed closely above the flooring of the vat, to permit the

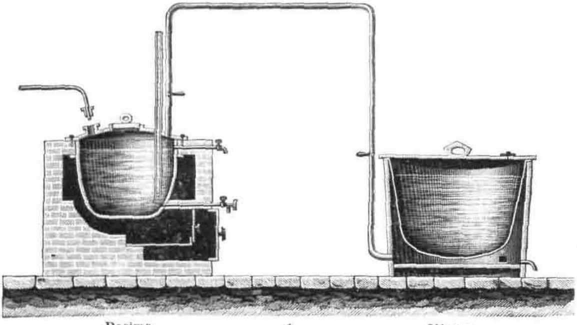


Fig. 61.—Steam Cheese Kettle (Perpendicular Section).

exit of the condensed water. In front of the inside end of this tube a clamp is fixed, which does not entirely lie on the floor of the vat, and by this means the exit of the steam is regulated. Where no steam kettle is available for the purpose, the steam may be prepared most easily in an ordinary built-up kettle, the lid of which is screwed on and provided with a wide opening. This opening is closed with a round iron plate, the weight of which gives to the steam the necessary slight pressure, and at the same time acts as a safety-valve. The steam conduction-tube passes through the lid, which is provided with a cock and a second tube open at both ends, and reaches almost to the foot of the kettle. This simple arrangement suffices if the contents of the cheese kettle are only to be heated to about 40° C. If, however, the temperature is to be raised to 60° C. or above, the operation is more quickly effected by working with steam under

greater pressure. In this case it is recommended to substitute a wooden vat with a metal casing which is provided with a bad heat conductor—a covering of wood, or a wooden jacket (fig. 61).

The necessary size of the water kettle for supplying steam is easily ascertained, if it be remembered that water converted into steam at 100° C., and under an atmospheric pressure of 760 mms., takes up approximately 537 heat units, and that saturated steam when it is condensed into water gives off the same quantity of heat. For example, if 1500 kilos. (328 gallons) of milk is the largest quantity which it is desired to heat at one time from 10° to 35° C., that is, to increase the temperature about 25°, 37,500 heat units will be required, taking the specific heat of milk to be equal to that of water. Every kilo. of steam yields, when perfectly condensed, at 100° C. 537 units, and when water is cooled to 35° C. 65 more units, altogether 602 units of heat. As 602 goes into 37,500 exactly 62·29 times, there must be used in the vat, if no loss is to take place, about 63 kilos. of water, that is, 63 kilos. of water must be converted into steam. With regard to the unavoidable losses, especially with reference to the fact that it is very convenient to utilize the hot water in the kettle as may be desired for any purpose, the size of the kettle should be double what is necessary, at least, that is to say, of such a size that it will contain 126 kilos. or more.

A good arrangement for the heating of a cheese-kettle with steam has many other advantages as contrasted with the heating over an open fire. Apart from the fact that it renders all operations which have to be carried out in the kettle distinctly easier, it is simpler, more cleanly, distinctly cheaper, since in addition to wood, turf, and peat, coal, brown-coal, or coke may be used, and it allows larger quantities of hot water to be prepared every time, and at the same time may be used for heating the dairy rooms with steam or hot water.

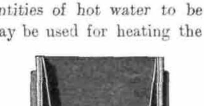


Fig. 62.—Oneida Cheese Vat (Perpendicular Section).

The large American cheese-vats are made out of tinned copper, white-metal, or tin, and are heated usually with hot water, occasionally, however, with steam. The most largely used in America is the Oneida cheese-vat (fig. 62). The other vats which are in common use are Armstrong's, Miller's, Jones's, Falkner Stuart's, Seeger's, and others (fig. 63). During the second half of the seventies, the experiment was made of introducing the American cheese-vats into Germany, which was assuredly not in the interests of German

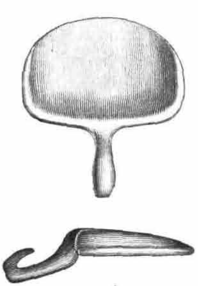
cheese-making. The attempt did not, however, meet with conspicuous success. Even had it succeeded, it is scarcely likely that there could be obtained in these vats a curd of a similar composition throughout its entire mass; and it is absolutely impossible to treat the curd in them subsequently in such a manner as to keep it of a uniform nature. The American cheese-vats are admirably adapted for dairies in which the object is to obtain cheese by means of daily work carried out on a large scale of manufacture, and where the

Fig. 63.—Cheese Tub.

largest possible quantities of milk are handled, rather than for the preparation of a cheese of the best possible average quality.

112. The Treatment of Curd before it is Moulded.—In the preparation of certain kinds of soft cheeses, the curd, after being coagulated, is only allowed to remain a short time in the cheese-vat to become thick, and is then immediately pressed into its shape by means of flat scoops, without having been previously cut into small pieces. In the preparation of most kinds of cheese, however, the curd is cut gradually into pieces, of such a size as is desirable for the properties of the cheese to be manufactured. It is advisable that all the pieces should be of a uniform size. In the curd which is cut into pieces for the different kinds of cheeses, the pieces vary, for example, from the size of an apple or a cherry-stone to that of peas or hemp-seed, &c. In the cheese-kettles, the curd can be cut easily, by means of a scoop, cheese-knives, or stirrers (figs. 64–65), into any size of piece that is required. This cannot be done in cheese-vats, where it is not possible to stir the curd. With

the American curd-knives (figs. 66–68), which consist of a row of brass knives placed parallel to one another, either horizontally or vertically, it is possible to cut the curd into large-shaped pieces of



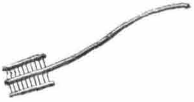


Fig. 66.—Curd Breaker.

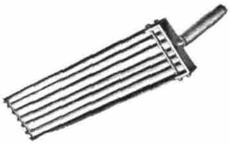


Fig. 64.—Cheese Ladles. *Fig.* 65.—Curd Stirrer. *Fig.* 67.—Curd Knife.

a certain size, but it is not easy to further reduce the pieces to a uniform smaller size in the vats themselves. To effect this purpose, a special implement is used in the American cheese factories, viz. the curd-mill, by means of which the curd, after being separated from the whey, is reduced into smaller pieces. The cheese-vat and curd-mill must be used together, for where one of these utensils is used the other cannot be dispensed with. It would be altogether useless, on the other hand, to grind the curd in a curd-mill where a kettle had been used for cheese making. For stirring the broken curd in cheese-vats, a special curd-stirrer is used (fig. 69).

Fig. 68.—Curd Knife with Horizontal Blades.

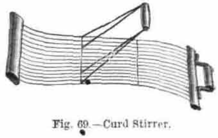


Fig. 69.—Curd Stirrer.

While the curd is being cut in the cheese vessels it becomes firmer, and poorer in water; in fact the smaller it is cut the less water does it contain. In the preparation of both kinds of hard cheese, the subsequent hardening is effected by means of another

heating. This is done by raising the temperature of the contents of the cheese vessels gradually, occasionally only a few degrees above the coagulation temperature, but occasionally also to a higher temperature, and in a few cases up to 75° C. In the preparation of Cheddar in most American cheese factories, the curd is submitted to a peculiar treatment. The cut curd is left, either under the whey, or after the whey has been removed, in a covered cheese vessel, at a temperature not far removed from the coagulation temperature, to lie until it has gained the proper degree of ripeness, that is, until it possesses a certain sticky property and a sour smell. The degree of ripeness is judged by testing with hot irons, after the method introduced by L. M. Norton. This test is carried out in the following way:—An iron bar is made red-hot, and then allowed to cool till it no longer shows redness in daylight. It is then brought into contact with a small piece of the curd, and the behaviour of this piece of curd is observed. If the curd cling to the iron, and is drawn out, when the iron is moved away, in threads which possess a length of from 1 to 2 centimetres, the proper degree of ripeness has been reached. Evidence that the ripening has not been carried on far enough is afforded by the curd not sticking to the iron at all, or if the ripening has been carried too far, the curd sticks in such a manner that long threads can be drawn.

All processes which have to do with the contents of the cheese-vat after the coagulation of the milk, and up to the process of shaping the cheese, and all precautions which are taken in these operations, should have as their object to maintain the curd of a uniform composition.

When the cheese is made in kettles, this last requirement can only be properly carried out if the process be thoroughly understood. As soon as coagulation has taken place, and the curd has become sufficiently firm, the lid is removed from the kettle in order to commence cutting, flat pieces of curd being scooped from the middle, where cooling goes on most slowly, with a cheese-scoop, and laid round the edge of the kettle for the purpose of keeping the curd in that part warmer. Thereupon, after the curd has become sufficiently firm, it is cut with wooden cheese-knives in a vertical direction, and then crosswise throughout the whole mass. The curd is then slowly and continuously turned horizontally with the cheese-ladle round the vat, and at the same time is being reduced to smaller pieces. The cutting is effected by the sharp front-edge of the cheese-scoop. When the curd has been reduced to a sufficiently small and firm

condition by this operation, during which a scoop is held in each hand, it is then worked with the stirrer until the pieces are of the desired size, and possess, at the same time, the proper elasticity, firmness, and dryness. During this process all the pieces of the curd should be kept in continuous movement, and at a similar temperature. In the large American cheese-vats, on the other hand, the whole mass of the curd, while it is being cut with the curd-knives, maintains its condition unchanged for a long time, often for thirty minutes, and even longer. The inside portions, and those lying underneath, cool much more slowly than the outside portions and those above, and the curd cannot possibly prove of uniform composition, since it does not possess throughout the whole mass continuously the same temperature.

The work of cutting must at first be conducted carefully and slowly, and with the application of increasing force, as the thickening of the curd progresses. If the necessary care and proper intelligence be expended, the whey obtained is clear, and only contains very few small pieces of curd.

Keevil has devised a special arrangement for cutting the curd in the kettle. It consists essentially of an upright cylinder, set in motion by a winch, to which four pinions are attached, with variously placed knife-blades. It would appear that this unsuitable apparatus is destined to fall into a well-deserved oblivion.

The subsequent heating should be carried on slowly and carefully, and in such a way that each individual piece of curd may become uniformly thick. If heating be carried on too quickly, the pieces become hard on their surface only, and the outlet of the whey from the internal portion is impeded or entirely hindered. Thus the mass of curd does not become dry or uniform enough, and the cheese turns out badly.

The method of working in the cheese vessels in use in the preparation of hard cheeses in Europe is more inconvenient and more troublesome than the American method of making cheese in large vats, but it is undoubtedly finer. It turns out, when properly worked, a curd of perfectly uniform composition, and renders it possible to influence, as desired, the condition of the curd up to the last moment before the formation of the cheese.

Before shaping, the curd is separated from the whey. When a kettle is used, this is generally effected in such a way that the curd at rest under the whey is taken out of the kettle with cheese-cloths. The whey is removed afterwards by draining, which is the simplest and best method. In making cheese in vats, the whey is let off from the curd by means of a tube provided with a cork, which is placed under the vat, and care is taken that the curd is retained as much as possible.

113. The Shaping of Rennet Cheese.—When the curd has assumed the proper condition, it is removed from the cheese-vat, in order to

be formed into cheese. A few kinds of the smaller rennet cheeses —cheese made from goats' or sheep's milk—are shaped by the hand. Most kinds of cheese, however, receive their shape by the curd being placed in suitable moulds without undergoing pressure, or by being subjected to an external gradually increasing pressure, continued until the single pieces are united together into a firm cohesive mass, and until the curd has been separated as perfectly as possible from the externally adhering whey. In the shaping of cheese, care should be taken to secure that the entire mass of the curd which has to form one cheese is perfectly uniform. If, for example, a very soft fat cheese is to be made out of soft curd, obtained at a comparatively low temperature, which is not equally fat in all parts, and after a process of slow coagulation, if this be not cut, but be put directly into the mould, all the mould should be filled at the same time, so that in each mould there will be approximately the same quantity of curd from the upper, middle, and lower layers. Finally, the contents of each mould, after being filled, should be thoroughly mixed. Furthermore, care should be taken that the whey run uniformly from the fresh cheese, so that not more may remain behind in one place than in another, and also that the whey which is separated out from the cheese may run freely away. As long as the cheese remains in the box, it should be often turned during the first hours when the cheese is still quite soft, and less frequently as the cheese becomes firm. By this turning of the cheese it is sought to secure the equal distribution of its moisture.

The rooms in which the cheese are kept for days in the chests should be neither too warm nor too cold, but should be maintained at an equable average temperature. At a high temperature (20° C.) active fermentation, accompanied with the development of gases, is to be feared, which makes the cheese porous, and in the case of too low a temperature (10° C.) the whey is not perfectly separated, a state of matters which has a very bad effect afterwards. Soft kinds of cheese, which quickly ripen and which do not keep long, are made in small moulds of different shape, while the hard keeping cheeses, on the other hand, which ripen slowly, are made in larger round chests, for which purpose chests made out of willow wood, or white-metal or tin are used. If the cheeses have to be pressed into the moulds or chests, they are wrapped up in cheese-cloths, and the chests used are made of strong wood or of metal, with sides in which holes are bored. When they have a bottom it is also perfor-

ated. The cylindrical moulds without floors, if they are not deeper than about 10 centimetres, are not provided with holes, and are so shaped that they can be placed either wider or narrower.

In England and America, the deep cylindrical-shaped chests, open above and below, are provided with holes. They are made out of strong white-metal, and are used in the manufacture of Chester, Cheddar, and Dunlop cheeses. In Switzerland, in the preparation of round cheese, round bent bands or strips of about the breadth of a hand are employed. They are made of selected beechwood, without holes, and are bound together by a strong string, which permits of their being drawn closer or opener as desired. In France, in the manufacture of green cheese, round bent bands made of zinc or white-metal are employed, which likewise admit of being drawn narrower or wider apart, and which possess no holes. In Holland, in the manufacture of Gouda cheese, bowl-shaped wooden moulds, provided with holes, are used.

If the round cheese-moulds in which the cheese is pressed are to perform their function in a proper manner, they must be of a durable nature, and must be so constructed that it can be at once seen if the discs between which the cheese is pressed are not exactly parallel, so that the whey may be allowed to flow away without hindrance, and the turning of the cheese and the changing of the cheese-cloths may be easily and conveniently effected.

The cloths which are used for wrapping up the cheese in the moulds, or for compressing them in the moulds, are specially woven out of strong hemp yarn. In order that the whey may easily run off, and that the cheese may quickly dry, these cloths must be coarsely woven (with a large mesh). The yarn must not, however, be too coarse, and must be strongly twisted, since in its use it is so completely soaked that the porosity of the cloths is decreased.

114. Pressing of Rennet Cheese.—The different kinds of soft cheeses are either not pressed at all, or only very slightly, by laying on weights, and without subsequently increasing the amount of the weight. There are, however, certain kinds of hard cheeses which are not pressed, but which are nevertheless very firm and dry. Hardness and dryness of the cheese is scarcely influenced by the strength of pressure applied, but almost entirely by the method in which it is manufactured, and by the subsequent treatment of the curd in the cheese-vat (fig. 70). The only object in pressing is to facilitate the expulsion of the whey from the fresh cheese, and at the same time to promote the cohesion of the single particles of the

curd, and to impart quickly to the cheese a smooth surface. It is quite impossible to regulate the moistness of the individual small parts of the curd by pressure. Pressure merely effects the expulsion of the whey which adheres externally to the curd. It is only possible to expel a very small portion of the whey enclosed in the inside of the curd particles, and in doing so a small portion of the mechanically enclosed fat is almost always expressed along with it. Pressure must always be carried out with care and intelligence if it is to effect the desired end. The pressure exercised should not remain the same during the whole period of pressure, but should be slowly and gradually increased along with the increase of firmness in the cheese. If the cheese be at first pressed too strongly when it is still soft, the curd on the surface is pressed so firmly together that the whey enclosed in the centre *cannot be perfectly* expelled, and the result will be that the cheese remains too damp, with the consequence that it subsequently becomes puffy. The same thing happens if the pressure be not sufficiently great, or if in using moulds which can be adjusted, either narrower or wider, the mould is made too narrow, so that the top and bottom and pieces of the cheese extrude between the hoops of the moulds and the pressure boards, on which the whole weight of the press rests.

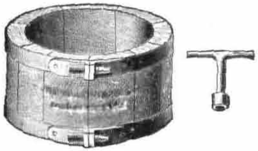


Fig. 70.—Wooden Cheese Vat to open with Key.

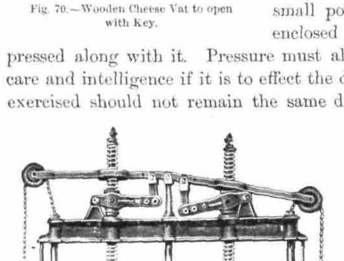


Fig. 71.—The "Two in One" Double Cheese Press.

We have already spoken in the previous paragraph of the necessity of frequently turning the cheese when in the press (fig. 71), and of replacing the damp cheese-cloths with dry ones, and of regulating the temperature of the surrounding air. The temperature of the air should not be allowed to rise in the press-room over 20° C., and should not be allowed to sink under 10° C.

The different kinds of cheese which are pressed only attain their best condition if the amount of pressure has been properly applied

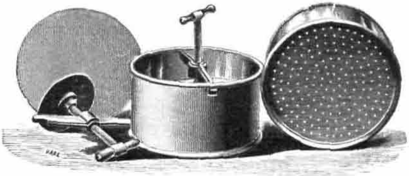


Fig. 72.—The "Gleed" Press for Soft Cheeses.

from the beginning, and has been gradually increased up to a perfectly definite maximum, which must be determined exactly by observation. As a rule, in cheeses having the same amount of fat, a large cheese is more strongly pressed than a small cheese; while a fat cheese is less strongly pressed (fig. 72) than a skim-milk cheese of the same size. Cheeses are generally pressed somewhat more in summer than in winter. Only cheese-presses in the use of which it is possible to carry out easily and conveniently the necessary regulations for efficient pressing should be regarded as good and useful. A good cheese-press should act, above all, in such a manner as to permit of continuous pressure being applied, that is to say, should be so constructed that the pressure can be easily and gradually increased at will, and at the same time it should show at any moment, how much the total pressure is, and how many pounds of pressure each pound of cheese is being submitted to.

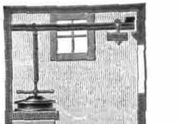


Fig. 73.—Swiss Lever Cheese Press.

The author prefers, to all other kinds of screw and box presses used in America and in England, the lever presses of the improved form made by Schatzmann (fig. 73), fitted with movable iron weights,

which are much used in Switzerland, Austria, and South Germany, and which not only meet all requirements perfectly, but are both easy and light to manipulate.

No doubt these lever presses require much space, and are, when made as large as is required for pressing Emmenthaler cheeses, somewhat heavy. This disadvantage, however, is of comparatively little importance. In addition to the screw and box presses, iron lever presses of an elegant appearance and occupying little space

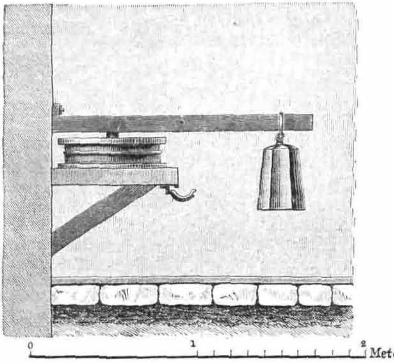


Fig. 74.—Lever Press.

are used in England and America. Such presses are worked by means of comparatively small and stationary weights in connection with two lever poles working upon one another, and in this way a great pressure is possible. These presses, however, are very dear, are liable to rusting, and without doubt, in the matter of utility, are inferior to the simple Swiss lever press.

A single lever with one arm furnishes the effective portion of the lever press. The lever has its support point lying on the end of the lever pole. The pressure, which is exercised by the lever through the action of a movable weight attached, is easily calculated, by the law of levers, if the weight of the lever pole be left out of account. The law of levers can be expressed in a double manner, by saying that an equal weight is present on the lever if the static momenta are equal to one another, or an equal weight is

present if the force and weight are in inverse ratio to the arms of the lever.

115. **The Salting of Rennet Cheese.**—A few kinds of soft cheeses, especially French soft cheeses, which are not allowed to ripen, but are consumed in the fresh state, are salted only when eaten, and not before. All other kinds of cheese are treated previously with salt partly during ripening. The object of salting is to render the cheese more pleasant in flavour, more easily digested, and to enable it to keep better. Many other important advantages, however, are obtained by salting. The salt, when in contact with the fresh cheese, attracts moisture, and is converted into a saturated brine, thus promoting osmotic processes in the cheese. On the one hand, the dissolved salt penetrates into the interior of the curd mass, and on the other hand, a liquid flows out of the curd mass, which contains the constituents of whey in a state of solution, especially the milk-sugar, lime, and phosphoric acid. As the author has shown by experiments, if the weight of the liquid which flows out of the cheese mass in a certain time be larger than the weight of the salt solution penetrating it, the result is that the salting process diminishes the percentage of water in the cheese and makes the cheese drier. If the fresh cheese have from the first been treated with an excess of salt, or if small quantities of salt have been added to it for weeks or months at definite intervals, its percentage of moisture can be either quickly or gradually diminished, and in the latter case, according to desire or requirements. This is of importance, since the activity with which the bacteria grow and exercise their characteristic action depends upon the percentage of water in the cheese, and because everything depends on the condition that ripening should proceed quietly and at an equable rate, and without any disturbing fermentations in the fresh cheese. Since salt not merely diminishes the percentage of water in the cheese, but also exercises a direct limiting influence on the action of bacteria, two important advantages are offered by the salting of cheese. In the preparation of very watery soft cheeses an endeavour should be made, under all circumstances, to carry out the salting as quickly as possible. This is effected by making the cheeses of a small, comparatively thin, loaf shape, strewing them with fine salt, and keeping them during the salting, and immediately afterwards, in specially constructed salt-rooms or drying-rooms.

Salt is added gradually, and in small portions, to the less moist, fresh, hard cheeses of finer quality. This is done because large hard cheeses, in which the osmotic processes go on more slowly than in soft cheeses, do not harden equally throughout their mass, but *become harder on their surface than they are in the interior, if too* much salt be added at once to them. The hard cheeses require a dry room, in which they must be allowed to remain until they have become sufficiently dry to permit of their being removed to the ripening-room or to the cheese-cellar.

Three different methods of treatment may be employed, as a rule, in practice, in salting cheese: (1) salting in a tub, (2) steeping in a *brine solution, and (3) strewing the cheese or rubbing the dry salt* into it.

Salting in a tub or steeping in brine is only resorted to in cases of hard cheeses. All kinds of soft cheeses are treated outwardly with dry salt, and the same is the case with the better and more valuable kinds of hard cheeses.

For salting cheese, only good, dry, finely-grained salt, of pure smell and flavour, should be used. If it be desired to have the salt reduced to a very fine condition, it might be put through a salt-mill before use.

With regard to the amount of salt required in the different kinds of salting, no definite regulations can be laid down, owing to a want of reliable observations. The least quantity of salt is used where the salting is carried out in a tub; somewhat more when steeping in salt brine is resorted to. With regard to the third method of salting, in the case of salting moderately heavy Emmenthaler cheeses, according to the author's observations, the amount of salt used should be about 6 per cent of the weight of the fresh cheese as removed from the mould, and in the case of very large and very slowly ripening cheeses of the same sort, more is necessary. In ripened cheeses the percentage of salt may vary from 1 to 4 per cent, being on an average about 2 per cent.

Salting cheese in the tub or vat is effected by kneading into the curd, with the hands, from 1 to 5 per cent of its weight of salt, before putting into the mould. The salt is dissolved very quickly in the whey adhering to the different small particles of curd, and removes water to a large extent from the curd, so that in moulding and pressing a comparatively large quantity of liquid runs off, and when it comes to be stored, the curd *has already become so dry that it can only throw off very little moisture*

into the air. As a rule the cheese is not further salted in the store, but is turned from time to time and brushed dry with a brush. Although this method of salting, in which the required quantity of salt which it is necessary to add to the cheese is added *all* at once, is very simple, it is only customary to use it in the preparation of certain kinds of cheese, since it excludes a more lasting and absolute action on the process of ripening of the cheese. It is only adopted in Europe in the preparation of poor hard cheeses of little value, the preparation of which is carried out in the cheapest and simplest manner. Often, however, it is used in British and American cheese factories even in the manufacture of fatty hard cheeses, when manufactured on a very large scale.

In steeping cheese in brine the cheese is left for from three to four days time in a saturated salt solution, is turned twice daily, and the upper surface, which rises above the salt solution, is quickly strewn each time with salt, care being taken that some undissolved salt is lying on the floor of the wooden steeping-trough. The saturated salt solution is renewed every eight to fourteen days, and is prepared by dissolving two parts of common salt in four parts of water. One hundred parts by weight of water at the ordinary temperature dissolve thirty-six to thirty-seven parts by weight of salt. In this treatment a layer is formed on the surface of the cheese 1 to 1·5 cm. thick, which becomes saturated with salt. This salt, if the cheese be not too large, that is, not over 15 kilos. in weight, is gradually distributed by osmosis throughout the whole cheese mass. According to the author's experiments, fat and skim-milk cheeses weighing between 7 and 15 kilos. lose, on being steeped for four days in a brine solution, five to six per cent of their weight. The cheeses which have been steeped are not further salted in the store, but are regularly turned, and perhaps washed from time to time with a dilute solution of salt. A fresh mass of cheese loses less moisture when it is steeped than when it is salted in the cheese-vat. Those cheeses, therefore, which have been steeped, keep both softer and damper than those which have been salted in the vat. Large hard cheeses, especially skim-milk cheeses, easily acquire, by means of the steeping, a very hard outer crust, which becomes detached from the inside softer mass as soon as the cheese has been cut for only a few hours, and left lying in a dry place. Many hard cheeses, which are treated for some time on the outside with dry salt, are finally left for twelve to twenty-four hours in a salt solution, chiefly for the purpose of giving them a hard rind.

In the third method of salting, the cheese is strewn with salt on its surface, or the salt is rubbed in. This is done at regular definite intervals, at first daily or every second day, and subsequently less frequently, and finally only when necessary. Salting is begun either immediately after the cheese has been removed from the mould, or after the lapse of two

days, when the cheese has become dry to a certain extent. In this method of salting, the important thing to be aimed at is to salt the entire surface of the cheese as equally as possible. This is effected by turning the cheese before every new salting, and, as soon as the salt is perfectly dissolved, by brushing the brine, with a brush especially designed for this purpose, over the surface of the cheese, and by rubbing the sides of the cheese more frequently with the salt than the top or the bottom. The cheese should not be turned till its surface has become sufficiently dry. As long as it yields an abundant brine, the cheese is kept in a special room—the salt or drying room,—care being taken that the brine is allowed to drain quickly off from the cheese. During this period, the fresh cheese is so saturated with water, and is so soft, that special precautions must be taken to maintain its regular shape. For this purpose rectangular small cheeses are laid on their ends in a row close to one another, and large round cheeses are surrounded with a wooden hoop similar to the hoop of the mould, or are firmly sewn up in a strip of cloth (England and America). As soon as the surface has become sufficiently hard the cheese has its wrapping removed, and the salting is carried out. Finally, when the salting has been practically completed, the larger cheeses are rubbed over from time to time with a cloth dipped in a salt solution, and the smaller cheeses are dipped once or twice into sour whey or a solution of salt. The method of salting is determined by the special conditions of the different kinds of cheese; the temperature and the relative dampness are regulated similarly, according to the nature of the cheese to be manufactured.

In order to permit sufficient time for the osmotic processes taking place in this method of salting, the salting process and the drying process are carried out very slowly and gradually, so that the cheese may become of similar character throughout its entire mass, a point of the highest importance for the process of ripening. The drying and hardening of the cheese may be facilitated or hindered by salting more strongly or more weakly, according to the circumstances and necessity, and thus the progress of the process of ripening may be influenced. In order to ascertain this correctly, it is necessary to watch carefully the ripening of the cheese in the store, and not to delay boring or cutting into the cheese, and examining a small portion of its interior.

In the case of small and light cheeses, the method of salting under discussion possesses the disadvantage that it is very laborious and consumes much time, and, at least in the case of large valuable hard cheeses, as, for example, the Emmenthaler cheese, demands much practical skill and attention, as well as a certain expenditure of force. On the other hand, in addition to the great advantages already enumerated, it possesses the recommendation that the cheese has only a thin external rind or skin, that

the destructive process of fungoid formation cannot take place in the cheese surface, and that, through the operations daily carried out in the cheese-cellar, attention is attracted in the course of the many observations made to any unusual behaviour on the part of the cheese, and any necessary action can then be taken without delay.

116. The Ripening-rooms of Rennet Cheeses (Cheese Cellars or Rooms).—From the drying-room the cheese is brought into the ripening-room, in which the process of ripening, which has already been started, and which has gone on to a greater or less extent, is carried to a conclusion. For cheeses which ripen quickly one ripening-room is sufficient, but for those which have to lie a long time the ripening-room should be divided into two portions, one for the fresher cheese, and the other for the partly ripened cheese. In the rooms in which the fresher cheeses are kept, the temperature of the air should be maintained somewhat higher than that of the air of the other ripening-room; but it need not remain exactly equable, though it ought not to be allowed a wide variation. The percentage of moisture should amount to about 85 to 90 per cent of the moisture the air can hold. The room should also be well ventilated, because moisture is constantly evaporating from the cheese. On the other hand, in the rooms for the ripening of the older cheeses, the temperature of the air must be kept as equable as possible, and comparatively low; while the percentage of moisture should be always from 90 to 95 per cent. The most favourable conditions for the ripening of newer and of older cheeses are between the temperatures of 10° and 20° C. Within these limits, a higher temperature is chosen for a more quickly ripening cheese than for a very slowly ripening cheese, and similarly a higher temperature is required for skim-milk cheese than for fat cheese of the same sort. If the temperature be allowed to rise over 20° C., ripening takes place more quickly but less uniformly, and the result is a large percentage of badly-made cheese. When exposed for some time to the influence of temperatures below 10° C., it has been found in practice that in the case of all cheeses undesirable changes take place in the ripening process. The temperature and the relative moisture of the air should be intelligently watched and daily noted, on account of the great influence which these external conditions have on the process of ripening. For this reason no ripening-room should be without a thermometer, and an instrument for measuring moisture—a hygrometer.

The stands on which the cheeses are placed in the ripening-room are made of wood. They are adapted to the form of the cheese, and the boards should be made of unpolished wood, and so wide that there is plenty of room to rest the whole surface of the cheese on them.

Flies of all sorts must be excluded from the ripening-room. Especial care should be exercised in this respect in the rooms in which soft cheeses are ripened. In soft cheeses, the larvæ of different kinds of flies are apt to become embedded, especially during summer, in the months of July, August, and September. This is more especially the case with those of a common cheese-fly (the *Piophila casei*). As cheeses in which the larvæ of flies are embedded ripen more quickly than other cheeses, such cheeses should be sold as quickly as possible—a practice which is not without risk. The best method of protection against such risk is to take precautions which are not difficult to carry out, to exclude flies altogether from the ripening-room. If, however, it is desired to destroy the larvæ which may have lodged in cheese, the best method is to dip the cheese repeatedly in a lukewarm strong liquid extract of common pepper.

In all hard cheeses which have been carelessly treated in the store-room, the common cheese-mite (*Acarus siro*) occurs often in enormous numbers, and in time converts the dry cheese mass into a powder made up of the excrements and skins of the mites casting their skin. In fresh dry hard cheeses they dig shallow passages or holes in the rind. Their action is less harmful than that of the cheese-fly, and they may be easily destroyed by rubbing the cheese over several times with oil, or with strong solutions of salt or spirits of wine, and by brushing the cheese-stand with soapy water.

Poisons, for the destruction of rats and mice, should on no account be used in cheese-cellars.

Up till the year 1880, the arrangement of the ripening-rooms for cheese manufacture was very unsatisfactory in Austria and throughout Germany, nd even in Switzerland, where it would be least expected. It was best in ance, in the cheese dairies in which the finest French soft cheeses were pared. Heating was effected only through ovens—in many cheese-ars even iron ovens. Of special ventilating apparatus none were known, for the relative percentage of moisture in the air was increased and maintained at the desired amount by the primitive method of introducing steam addi onally into the ripening-room. Such an arrangement was that of com -Huber, for example, who introduced into Switzerland, at the begin-

ning of the year 1880, a method which he had devised of treating round hard skim-milk cheeses. The unsatisfactory arrangement of cheese-cellars not only increased the difficulty of treating the cheese in the store-room, but also the whole manufacture of the cheese, inasmuch as it was necessary, if it was wished to avoid serious mistakes, to take many precautions, in the preparation of the cheeses in the cheese-rooms, against the harmful influences to which they were subsequently exposed in the cheese-cellars. At present, in the ripening-rooms of all the larger and better equipped cheese factories, steam and warm-water heating apparatus are provided, as well as apparatus for regulating the ventilation. Quite lately W. Helm, a civil engineer, has attempted to perfect the arrangement of the ripening-rooms for cheese manufacture. In the first place, according to him, it is advisable to build the cheese-cellars either without windows, or to provide them with very few and very small windows. The fewer windows present, the more independent is one of the conditions of weather, and the easier it is to maintain the temperature and relative moisture equable throughout the whole year. Further, he would lead through the cheese-cellar, already provided with a warm-water heating apparatus, a continuous stream of air, saturated with water vapour, at a temperature of about 10° C., before its entrance into the cellar, in a room specially constructed for this purpose. The stream of air can be increased or diminished as desired. It enters the cellar up above in the neighbourhood of the roof, passes over the heating tubes, and is warmed by them, and by this warming loses somewhat in its percentage of moisture. It travels through the cellar, and finally leaves it by means of canals which have their exits near the floor. By due regulation of the rapidity of the current of air and of the heating, it is possible not merely to bring the temperature and the moisture of the air to exactly the desired condition, but also to maintain it equally at the desired temperature. Up till now only a few cheese-dairies have been provided with this arrangement. Unfortunately it is somewhat costly, and on this account it has not come into general use, while reliable details in regard to its efficiency in working for a prolonged period, and its technical and economic value, have not yet been furnished. Every improvement of the ripening-rooms for cheese manufacture must be regarded as an advance in the interests of dairying.

By the relative percentage of moisture of the air, is understood the amount of the moisture, expressed in per cent, which the air under the existing temperature and barometric pressure is able to absorb and become saturated with. For example, a relative percentage of moisture of the air of 75 per cent, would indicate that the air under the existing conditions of temperature and air pressure only contains three-fourths of the water vapour which would be required to bring it to the point of saturation.

117. The Art of Cheese-making.—The art of cheese-making is much more difficult than that of butter-making. In cheese-making a large number of different conditions have to be reckoned with, and their different influences have to be considered and weighed in relation to one another, so that they may all conduce to their definite and prescribed end. To do so requires a certain measure of skill and experience. He who understands how to manufacture successfully even one kind of fine cheese, in different places, that is, under different surrounding conditions, will also assuredly succeed, after a short amount of tuition or intelligent description, in the manufacture of other kinds. The art of cheese-making requires two different qualifications—a clear understanding, on the one hand, of the nature and action of all the processes which come into play in the manufacture of cheese; and, on the other hand, the particular object which must ever be kept in view in all these processes, and in the manufacture of all kinds of cheese.

There is no doubt that the different kinds of cheese owe their particular properties or characteristics to the action of different definite bacteria, or classes of bacteria. Since it is possible to prepare any kind of cheese from a given quantity of milk in a given place or at any time, and according to its nature to obtain it from this milk, it follows that all the kinds of bacteria which are necessary for the manufacture of the cheese in question must be present universally and invariably in the milk. These bacteria must have an extraordinarily wide occurrence. The art of cheese-making consists in the preparation of the fresh cheese mass of each different kind in such a way that those kinds of bacteria which are active in the ripening of that particular cheese must be developed to a predominant extent. It is on this account that cheese-making employs the most various means. In the first place, the separation of the milk may be effected by acids or by rennet. In the preparation of rennet cheeses, it is in the power of the operator, according to the methods and kind of coagulation effected in the milk, to produce a curd harder or softer, and, according to the state of division, to make it damper or drier; to determine, by regulating the percentage of fat in the liquid which is being converted into cheese, the structure of the curd; by subsequent heating to different high temperatures to lessen the percentage of moisture in the curd according to requirements; to weaken the energy of the development of the more susceptible kinds of bacteria; by the application of high temperatures, in the process

of subsequent heating, and by pressure, to regulate the amount of whey remaining in the cheese between the small particles of curd; and by salting to reduce, more or less slowly, to the necessary smallest quantity, the percentage of moisture in the fresh cheese. But this *does not exhaust the means used in cheese manufacture by which it* is possible to control, to any desired extent, the most varied conditions. It is possible to prevent from the very first the growth of a large number of bacteria, and to direct the ripening into a particular direction, by attempting to maintain the curd in a perfectly sweet condition; or by imparting to it from the very first a sour reaction, by the addition of sour liquids to the milk to be converted into cheese; or by souring it after it has been put into the cheese-vat; or by letting it ripen; or by saturating the curd mass before it is put into the mould with liquids containing rapidly-developing cultures of certain kinds of bacteria, as is done in the preparation of certain kinds of Dutch cheese.

In these processes, which up to the present time have been carried out in practice by instinct, as it were, and wholly on the basis of observation and experience, it must always be felt that the success of all the operations is connected with one indispensable qualification, viz. the qualification of the very highest importance, that in cheese-making it is necessary to start prepared to exercise in all the operations *constant care and attention. This qualification consists in conducting* each operation, whatever it may be, in such a manner that the entire mass of curd may become throughout of a perfectly similar condition. The author has not failed in the foregoing pages, in describing the individual processes of cheese manufacture, to emphasize this fact. It has long been shown in practice that the equal development of the ripening and successful results can never be expected if the cheese mass be not perfectly uniform in quality throughout. If this condition be neglected, the result will be disastrous, especially in the case of the manufacture of large cheese, of which only one or two separate cheeses are made at one time. Whoever recognizes, perfectly or clearly, the great importance of this qualification, has grasped to a certain extent the secret of cheese manufacture, and has found the key to a proper understanding of all its rules. If this idea be once fully realized, and if the rules above described, which have been given for the manufacture of cheese, be put to the test by accurately following them, it will be found that they inevitably lead to satisfactory results.

118. The Ripening of Cheese.—The chief constituent of all fresh cheese—the paracasein—is only very slightly soluble in water. It is on this account that fresh cheese, unless it be in a perfectly soft, almost gelatinous or buttery condition, is not enjoyable or palatable. In order to render it palatable, it is allowed to ripen, that is, it is kept under suitable conditions (§ 116) till decomposition of its constituents, which takes place as soon as the bacteria present in the cheese mass are cultivated and developed, is permitted to go on for a certain time. When this limit is reached the cheese is known as ripe. Ripe cheeses of any kind, which have been kept for just the proper length of time, possess the best flavour and the highest value which the kind of cheese can attain to.

The most important process, in the ripening of cheese, is the change which the paracasein undergoes. From this chief constituent of the cheese simple compounds are formed, which are soluble in water; then compounds which resemble, and which are akin to the albuminoids. Among these, peptone, probably also caseo-glutin, subsequent numerous further products of decomposition, among which are amido acids, phenol-amido proprionic acid, and leucin and tyrosin, have been identified, and finally ammonia salts. The soluble bodies which are held in the water present in the cheese, determine by their quantity and condition the flavour of the cheese, and alter the appearance and consistency of the cheese mass by penetrating through its pores.

Milk-sugar, which is only present in fresh cheeses to a small extent, quickly vanishes under all conditions. It is either entirely converted into lactic acid, from which further decomposition products—for example, butyric acid—may be formed, or it is changed into a form of fermentable sugar, and then gives rise to a remarkable fermentation, accompanied with development of gas. This fermentation is effected by bacteria, and yields, in addition to small quantities of alcohol and other substances regarding which we know nothing, chiefly carbonic acid, which is produced in large quantities, and hydrogen. With regard to this interesting phenomenon, as well as with regard to the formation of bubbles in the cheese, investigations are at present being carried out, which will doubtless very soon furnish more exact information. In what way the conversion of milk-sugar and its products influences the other processes of decomposition taking place in the cheese mass, or acts upon the digestibility and the condition of the cheese mass, or the flavour of the cheese, we

cannot as yet say. It is highly probable that the milk-sugar generally, if not perhaps entirely, directly causes the formation of all the pores in the cheese, the small and very numerous holes in the American, English, Dutch, and other hard cheeses, as well as the holes about the size of beans which are unconnected but regularly distributed in the Emmenthaler.

The fat is very little affected to all appearance by the decompositions going on in the ripening cheese mass. At any rate, in no case do the products of fat decomposition exercise a noticeable influence on the characteristic properties of the different kinds of cheese. Probably the only influence which the fat exerts on the characteristic nature of the cheese is in affecting its pleasant flavour, and the tenderness and softness of the cheese. These properties depend on the quantity of fat present. It is not impossible that the fat hinders and retards, according to the amount in which it is present in fat cheeses, the action of the albumin bacteria on the paracasein.

Of mineral constituents of the cheese, a portion, especially lime and phosphoric acid, are lost by passing away with the salt, in the salting of the cheese, by the process of osmosis. Whether, and to what extent, the mineral salts are directly or indirectly split up by the growth of bacteria in the ripening processes, is not known.

The percentage of water in the cheese becomes distinctly less during ripening. A portion of the water evaporates or flows away in the salting of the cheese with the salt solution, and another portion is lost by the water forming in the ripening process new combinations, and entering into chemical combination.

The slowly-ripening hard cheeses do not appear, during the ripening process, to suffer any appreciable further loss of weight, unless by that due to loss of moisture. Up till now, at least, it has not been discovered that any loss of the volatile ammonia salts, volatile fatty acids, or methylamine occurs. On the other hand, it is highly probable that the rapidly-ripening soft cheeses, possessing a penetrating odour, suffer a loss of their organic substance. What constituents of the cheese are decomposed in these losses, and in what way the loss takes place, is not yet known. It has also not yet been demonstrated with certainty that there is a development of small quantities of *indol* and *skatol* in the ripening of cheeses possessing an odour, nor has it been ascertained whence the free butyric acid is derived, which it has been proved is invariably present in ripening cheeses, and which is present, in large quantities,

in ripening soft cheeses. The lactic acid derived from milk-sugar cannot be the sole source, and hence it must be assumed that, in the decomposition of albuminoids, butyric acid is also formed. It seems to be certain, at any rate, that it is not formed from the fat of the cheese.

The much-discussed question, as to whether in the ripening of different kinds of cheeses the percentage of fat in the cheese increases, that is, whether in the ripening process neutral fat can be developed from albuminoids, which is not inconceivable, has not yet been satisfactorily nor assuredly decided. If such a formation actually takes place, it probably results in a synthetic manner from the combinations which are effected by the action of bacteria on the albuminoids. Nor is it inconceivable that small quantities of neutral fats may be derived from the lecithin of the butter-fat. Interesting as this question in itself is, it does not possess any practical significance, since, under any conditions, it can only give rise to the formation of comparatively small quantities of fat.

The author does not regard it as probable that in the ripening of rennet cheese the rennet used for coagulating the milk exerts any subsequent influence.

It will be observed that the development of certain kinds of micro-organisms concerned in the ripening of cheese is adversely affected by light. It is to be recommended, therefore, in all cases, that the rooms in which the ripening processes are carried on should be kept dark, and that they should possess very few windows—a point which is advisable on other grounds, already stated in § 116.

The peculiar characteristics of the numerous different kinds of cheeses depend on the progress of the many processes, some very complicated, which have been here shortly described. The older researches on the chemical changes which the caseous matter suffers in ripening contain little that is worthy of note. On the other hand, the elaborate and exact researches carried out by E. Schulze, U. Weidmann, B. Rose, and F. Benecke on the ripening of Emmenthaler and some other kinds of Swiss cheese, supply very interesting glimpses into the process. These may be shortly epitomized as follows:—

In ripening and in ripe cheeses of the kinds mentioned, in addition to unchanged paracasein, and in addition to at least one characteristic nitro-

genous body similar to caseo-glutin, of which more is not known, there i *found a body which stands in its properties between albuminoids an* peptones; further, leucin, combined with amido acids in comparatively larg quantity, as well as tyrosin and phenol-amido proprionic acids—the last two in smaller amounts—and, finally, ammonia, but in very small quantities, are all developed. Of ammonium magnesium phosphate, lactic acid, butyric acid, and peptones, *ripening cheeses contain only small quantities.* Only *Vacherin* and *Bellelay* cheeses have been found comparatively rich in peptones. The loss of their substance which the ripening cheeses suffer is only very slight. That the older the cheeses become the greater are the amounts of the albumin decomposition products, was shown by the advance made in the ripening processes with the lapse of time. Milk-sugar is not present in ripe cheeses, nor are xanthin bodies found in them. A *separation of fat only takes place in very small quantities, and the increase of the* percentage of tri-glycerides in the cheese is not noticeable. Whether free non-volatile fatty acids are present in cheeses could not be decided. It is not impossible that the different caseo-glutins, which do not perfectly agree with one another in their physical behaviour, are present in the *different ripe cheeses, and it appears very probable, from this fact, that* nuclein is gradually decomposed in the ripening process. In ripe Emmenthaler cheeses, on an average, about 80 per cent of the entire amount of nitrogen belong to bodies of an albuminoid nature, and 20 per cent to products of the decomposition of albumin. In skim-milk cheese, prepared after the manner of Emmenthaler cheese, the changes taking place in the material of the cheese in the ripening process are not exactly the same as those taking place in the fat cheese. *The watery extract is richer in* albumin, and poorer in albumin decomposition products. The latter also shows a higher percentage of nitrogen than the fat cheeses. The extract of skim-milk cheeses leaves behind, when strained, a very unpleasant-smelling residue.

The above-mentioned researches chiefly concern themselves with the chemistry of ripening. *On the other hand, the researches of* Cohn, Benecke, and Duclaux deal chiefly with the study of the ferments concerned in the ripening of the cheese, and are bacteriological in their nature. Duclaux describes a number of enzymes which are separated by bacteria, and which co-operate with them in the ripening of cheese. The bacteriological experiments which have been carried out on the ripening of cheese have partaken of the character of preliminary experiments only. They have merely dealt with the surface of the subject, and have not been at all exhaustive. Nevertheless, they have been very serviceable in

opening up a new point of view, and they have pointed to the way along which light on the process of the ripening of cheeses will be gradually obtained. This way lies in the closely intimate relation that exists between the investigations of bacteriology and chemistry. To begin with, systematic attempts have been made to discover by means of these two sciences what kind of bacteria are at work and in what way the chief phenomena are brought about, as, for example, the change of paracasein, the change of milk-sugar, and the formation of holes in the cheese; also what effect bacteria and the lower forms of fungoids have on the fat, &c. It may perhaps be soon proved that the processes taking place in the ripening of cheese are neither so complicated in degree, nor so many-sided, as we are at present inclined to think.

The functions performed by the lower fungoids in the manufacture of cheese have been previously discussed in § 43. As has already been mentioned, it must be assumed that milk universally and invariably contains all the different kinds of bacteria which act in the manufacture of cheese. It has also been already pointed out that fresh curd resembles to a certain extent a field which is richly sown with the most varied kinds of bacteria, but on which no kind of bacterial vegetation is permitted at that stage to predominate. If it be observed that the milk of individual cows, or the milk of a whole herd, has proved itself useless for the manufacture of cheese, since, when utilized for this purpose, even with the observance of the greatest care and with the most intelligent work, certain phenomena of ripening take place prematurely or in a disturbing manner, or the flavour of the cheese is unpleasant, or there is any other failing manifested, the author is inclined to believe that this does not, as a rule, arise from the fact that the milk has become contaminated with peculiar bacteria not generally present. Such phenomena are probably rather to be traced in most cases to the fact that some of the common sorts of bacteria of milk have developed with special luxuriance, and have changed the properties of the milk to a certain extent, a state of matters which has adversely influenced the development of the other common kinds, and has given the ripening process an undesirable direction. It must not, however, be denied that occasionally strange kinds of bacteria, which have nothing to do with the ripening of cheese, find their way into the milk, and are thus able to disturb the manufacture of the cheese. Milk, when it is coagulated, ought not, as a

rule, to contain any one-sided predominating bacterial vegetation; *but this can only be secured if the milk has been obtained from* healthy cows, and if in the process of milking, as well as afterwards, everything has been done in a clean and careful manner. If disturbances should arise in milk derived from different herds in a cheese manufactory, and it be desired to discover from what herd the *milk which is unsuitable for cheese-making has been obtained, this* may often be effected by the application of the milk fermentation test or the rennet test described in § 33.

It is by no means always easy or simple to conduct and regulate the many different operations of cheese-making in such a manner *that the cheese manufactured from day to day will be of equally* good quality. Occasionally influences have to be dealt with which defy all precaution; for example, the dealing with milk which is unfit for the manufacture of cheese. It is therefore quite impossible in cheese dairies, even in the best of them, to avoid turning out, *along with the more or less successful cheeses, a greater or less* percentage of failures. The causes which lead to failures in the manufacture of cheeses, and which thus damage the cheese industry, may be of very different kinds. Against a few of them there is scarcely any safeguard. The most of them, however, and those *which are of most common occurrence, may be combated by the* exercise of the requisite amount of attention and skill.

The commonly occurring disturbances and defects in cheeses are, for example, as follows:—

(1) Those common to all sorts of cheeses. The cheese becomes inflated, owing to the fact that the process of ripening takes place too soon, and proceeds *at too rapid a rate, a defect which may be generally, if not* always, overcome.

(2) In soft cheeses the cheese runs, that is, it loses its shape, and is changed into a sticky, gelatinous mass (refractory), a defect which is the result of too quick ripening, and can always be avoided.

(3) In soft cheeses the cheese becomes the prey of flies, which can always be prevented.

(4) In hard cheeses, the formation in certain places on the surface of the cheese of fungoid growths, which convert the cheese into a dry white powder, so that gradually larger or smaller holes are formed, beginning on the surface of the cheese. This is always preventible.

(5) In cheeses of all kinds, the occurrence in the cheese of a bitter or a soapy flavour. This is a rare occurrence.

(6) In hard cheeses, the formation on the surface of the cheese of red patches, or the coloration of cheese in blue or yellow patches, or the discoloration of the entire mass of the cheese, so that it presents a bluish-gray or black appearance. This happens very rarely.

(7) In soft cheeses and sour-milk cheeses, the development of poisonous properties in the cheese. In cheeses which have ripened too quickly, or which have become overripe, certain kinds of bacteria develop, which give rise to the formation of toxines. The cheese exercises poisonous effects, and when eaten causes the development of symptoms, such as are seen in *gastro enteritis toxica* or in *cholera nostras*. Poisoning with old cheese is very rarely accompanied with fatal results.

Again, almost every kind of cheese has its special disease. To go into these even shortly would lead us far afield.

The chief expense in cheese-making is due to the ripening. Apart from the loss in weight which the ripening cheese suffers, and the waste which this causes, the treatment and supervision of ripening cheese demand the expenditure of much time and labour, and the capital which is invested in the manufacture of cheese is locked up through the long period during which ripening lasts. By making the curd less dry, and by raising the temperature of the air in the store-room, the ripening period may be considerably shortened, but this can only be effected at the expense of the average good quality of the cheese. This practice would prove practically advantageous only under exceptional circumstances, as in the case of a very extensive trade, and even then it would have to be carried out with very great care. As a rule, the loss incurred from the production of a number of spoiled cheeses would be greater than the saving effected on the cost of manufacture. As a rule, the best course, from an economical point of view, is to take precautions to secure a slow and equable progress of the ripening, and not to depart from the average period, which must be regulated as experience has shown to be best, if the cheese is to acquire the best possible condition. In all fermentation processes the best and finest results are obtained from the processes that require comparatively the longest periods of fermentation.

In order to prepare cheeses of different kinds for the market, they are subjected to special treatment, partly during the ripening process and partly later. They are scraped and brushed, their surface is polished, and is coloured with annatto, turnesol (*Crozophora tinctoria*), and other colours, rubbed over with oil, wine, beer, extracts of leaves, &c., are ironed,

that is, a hot iron having a flat surface is run over them in order to give them a horny surface, or they are smoked in the smoke of firewood. In these operations, the object aimed at is to attempt to improve the appearance of the cheeses, and also their keeping qualities.

Small soft cheeses, with oily surface, which possess a sharp smell, are packed in tinfoil. The covering of tinfoil gives to the cheese not merely *a better appearance, but facilitates the keeping of it, and makes its retail* sale pleasanter, since it keeps the soft cheeses firm, and retains the penetrating odour. As, however, the tinfoil used in commerce often contains as much as 20 per cent of lead, the question arises as to whether the packing of cheese in tinfoil containing a large quantity of lead does not threaten the health of the consumer. Experiments carried out on this subject, have proved that cheeses which have been packed in tinfoil, containing a high *percentage of lead, only contain lead on the outer portion of their rind, and* that the percentage of lead in this portion is only ·5 per cent, and that a short distance inwards from the rind no lead can be detected. If, therefore, the precaution be taken not to eat the rind of cheeses which have been packed in tinfoil, there is no ground for fear on this account.

A sample of tinfoil has been found to contain

Tin, ...	96·21
Lead, ...	2·41
Copper, ...	·95
Nickel, ...	·29
Iron, ...	·09
	99·95

In Algau, in Bavaria, it is customary, in the case of brick-shaped cheeses, to pack them when they are only a quarter ripe, the cheese being first wrapped up in firm unglazed paper, and then in tinfoil. A skilled cheese-maker can wrap up in an hour 80 to 100 separate brick-cheeses in tinfoil.

The preparations for hastening the manufacture of sour-milk cheeses, *introduced by Trommer in 1846, which consisted in treating* the curd with ammonia, carbonate of ammonia or soda, in order to give to the fresh cheese the appearance of old and regularly-ripened cheese, need only be mentioned here as an historical curiosity.

119. The Different Kinds of Cheese and their Classification.—Of the very large number of different cheeses now known, a not inconsiderable portion were known to the nations of antiquity. Fresh whey and fresh watery cheese were partaken of in very early times, several thousand years before the beginning of our era. Certain

methods of treatment were also known by means of which the cheese could be made to keep longer. Probably it was cheese made from sheep's or goats' milk, no doubt sour-milk cheeses, that were first prepared in the olden times. Martini and Hornigh have selected a number of notices, from which they infer that the knowledge of cheese is a very old one, and that men early came to prize the manufacture of cheese, and devoted great attention to the preparation of the different kinds. Aristotle (384–322 B.C.) wrote concerning the use of different kinds of rennet, and in Varro (115-25 B.C.) we find descriptions of the influence of bulling, of age, of food, and other conditions, on the properties of the milk of the different mammals, and the cheese manufactured therefrom. In Pliny (23–97 A.D.) we learn that in his time a long catalogue of different kinds of cheese was drawn up, and Columella, who lived in the first century A.D., already wrote on the influence of temperature on the thickening of milk with rennet, of the necessity in the pressure of cheese of gradually increasing the pressure in the cheese-moulds, of salting with dry salt, and of salting with brine, of smoking cheese, and of the preparation of herb cheeses. From the writings of Roman authors, we further know that in many districts in the middle and south of France, for example, in the present department of Aveyron, in which Roquefort is situated, cheese was prepared and sent to Rome in the first centuries of our era. The oldest reliable records of German cheese-making belong to the time of Charles the Great. At that time, it would appear that the preparation of cheese was regarded as more important, and was carried on in a wider area, than the preparation of butter. The most thorough understanding of the art of cheese-making generally, and of the nature and importance of all the operations which it involves, is to be found in Switzerland, as is proved by the fact that the Emmenthaler cheese, which is the finest of all kinds of cheese, and the preparation of which in perfect condition is more difficult than the preparation of any other kind of cheese, is made there.

In the following paragraphs the author will attempt to enumerate shortly the different kinds of cheeses. A complete description of the preparation of all of them is naturally not possible in this work. The author will rather describe in fuller detail the process of the manufacture of certain kinds of cheeses, in order to illustrate the general principles of cheese manufacture. Such cheeses as are universally known and esteemed will be selected, and such

as may, at the same time, be regarded as typical, to a certain extent, of the larger groups of cheeses. He limits himself to this, because he doubts if a more detailed description, unless it went into all characteristics in an exhaustive manner, would possess any practical value. It is not possible from a short summary and description to prepare, with good results, new foreign kinds of cheeses. This can only be effected by studying the manufacture locally, or by having at hand a good treatise which contains descriptions of the most minute detail. In such monographs the literature of the subject is comparatively poor. Detailed descriptions, although not so thorough as to permit of working from them alone, are to be found, for French cheeses, in Pouriau's excellent work, and for American cheeses, in L. B. Arnold's work, on this subject. An intelligent description of cheese manufacture will be also found in Dr. Von Klenze's *Handbuch der Käserlitechnik*. Finally, descriptions of cheese manufacture are to be found in B. Martiny's book, and in the author's work on the subject.

In the following epitome, the two chief groups of cheeses are rennet cheeses and sour-milk cheeses. The rennet cheeses the author divides into cow, sheep, and goat milk cheeses, &c., and the cheeses of the larger portion of this class, viz. the cheeses made from cows'-milk, are further divided into soft and hard cheeses. In the different paragraphs are given the names of the cheeses and the countries where they were originally manufactured, arranged in alphabetical order. Cheeses are designated as fat when they are made of whole milk, half fat when they are made from half whole-milk and half skim-milk, and skim when they are made from skim-milk. No hard and fast division can be drawn between soft and hard cheeses; but as is necessary from the classifiation adopted, in the cases in which it is doubtful whether the chesses should be brought under the one class or the other, the author classifies as soft cheeses those which have a more or less smeary and soft substance, and as hard cheeses those which are friable and dry.

As cows'-milk sometimes contains almost as much, sometimes somewhat more, and sometimes somewhat less fat than nitrogenous matter, the ratio between fat and nitrogenous matter does not vary much in fresh fat cheeses—between that of 50 to 50 (taking 100 as unity). If this varies to such an extent that 60 to 40 is the ratio, the milk which has been made into cheese has had cream added to it, and the cheese is a super-fatty cheese. In half-fat cheeses the

ratio approximates to 33 to 67, and in skim-milk cheeses, according to my investigations, may be from 12 to 88.

120. Rennet Cheese of a Soft and more or less Oily Character, made from Cows'-milk—Soft Cheeses.—In the preparation of soft cheeses, the milk is set at comparatively low temperatures, and the coagulation period lasts for a comparatively long time. Success depends essentially on the fact of effecting the most thorough possible separation of the whey and the curd. Soft cheeses are not subjected to strong pressure. After the coagulation and cutting up of the curd has been done, it is placed in the moulds and allowed to drip, and finally is subjected in the store to treatment, which consists in salting the cheese, drying it, and supervising its ripening. Individual kinds of soft cheeses obtain their peculiar properties only by development on their surface during the ripening of certain kinds of micro-organisms. The ripening of all soft cheeses resembles essentially a slow process of decomposition, taking place from outside inwards. Most kinds of soft cheeses are allowed to ripen before use, only a few kinds being used in their perfectly fresh condition. Among the soft cheeses are the finest and most highly-prized table cheeses.

(*a*) Cheeses which are used in a fresh condition:—

1. *Belgian.*—Maquée or Fromage Mou.

2. *England.*—Cream cheese.

3. *France.*—Fromage de pure crème; Fromage a la crème; Fromage double crème dit Suisse; Bondon, Bondon de Rouen or Fromage double crème, dit Bondon; Malakoff; Petit Carrés; Anciens Imperiaux; Gervais and Chevalier; Coulommièrs; Fresh Neufchatel cheese; Fromage maigre, de Ferme mous, a la pie; Fromage blancs.

4. *Italy.*—Mascarponi, Giuncate, Mozarinelli.

5. *Austro-Hungary.*—Gloire des Montagnes and Lady cheese.

(*b*) Cheeses which are allowed to ripen before being used:—

1. *Belgium.*—Limburg cheese, Remoudou cheese.

2. *Germany.*—Algäuer, Remoudou, Moriner and Brioler, Münster or Box cheese, Strasburg, Hohenheim.

3. *England.*—Wiltshire, Cream, Slipcote.

4. *France.* — Brie cheese, Coulommièrs, Olivet, Ervy, Troyes, Chaource, Barbery, Langres, Spoisse, Soumaintrain, Mont d'Or, Sénecterre, Auvergne, Géromé, Bacherins, Fromage de foin, Camem-Livarot, Macquelines, Thury en Balois, Mignot, Neufchatel,

Bondon de Rouen, Gournay, Malakoff, Pont l'Eveque, Anciens Imperiaux, Carrés affines, Boid Billiers, Tuiles de Flandre, Larrons, Dauphins.

5. *Italy.*—Stracchino fresco, Stracchino de Milano, Stracchino quadro, Gorgonzola, Calvenzano, Robbiole, Robbiollini, Formagelle.

6. *Austro-Hungary.*—Swarzenberger Mariahofer, Tanzenberg, Grottenhofer, Hagenberg castle, Steierich, Josephine, Trappisten.

7. *Switzerland.*—Bellelay, Tetes de moins, Bacherins.

8. *Chili.*—Chili Soft cheese.

The Preparation of Neufchatel Cheese.—Neufchatel cheeses (Bondons or Bondes) are highly-prized table cheeses. They are of small size and cylindrical shape, and weigh ·12 to ·13 kilo. They are chiefly made in the department of the Seine-Inferieur. Their diameter is 5 cms. and their depth 6 cms. Two kinds are distinguished, fat cheese, *à tout bien*, and skim-milk cheese. The fat cheeses are prepared as follows:—The warm milk is strained into stone jars, in a room having a temperature of 15° C. It is treated with rennet, and the jars are placed in wooden boxes and are covered with a woollen cover. After twenty-four hours the curd is turned in another room into a basket made of willows, and is covered over with a fine cloth. It is then allowed to drip for twelve hours over a trough. The curd is then transferred in a cloth to a vessel with holes in its sides, is covered over with a wooden cover and weighted down with weights. When it has thus been pressed for twelve hours, the curd is transferred to another cloth and thoroughly worked. If the mass be not sufficiently soft, fresh curd which has not been allowed to drain is added to it. It is then filled into moulds of cylindrical form, 5·5 cms. high and 6 to 7 cms. broad, made out of tin. It is then firmly pressed with a stamp, and smoothly cut above and below with a wooden spatula. The little cheese is then removed from the mould. After the cheese has been spread on all sides with salt—about 500 grams are used for 100 cheeses,—the cheese is laid on boards over a trough to drain. When draining has proceeded for twenty-four hours, it is brought into the ripening-room on a board on which fresh straw is placed. Here it remains from fourteen days to three weeks without being disturbed, except by being frequently turned. If the cheeses become covered with a bluish-green mould, they are placed on fresh straw in a special division of the ripening-room sufficiently widely apart, and pressed and turned from time to time until they show on their surface flecks of moulds, which, as a rule, is the case after three weeks. The cheeses, when they have attained this condition, are ready for sale, but they only reach their highest perfection fourteen days later. The period of ripening requires on the whole from six to eight weeks. Thoroughly

ripe Neufchatel cheeses can be kept for two months without being much affected. 100 kilos. of milk give on an average 22·5 kilos. of fresh cheese.

121. Rennet Cheese of a Firm Character, made from Cows' Milk—Hard Cheeses.—The hard cheeses gain their condition by coagulating the milk at higher temperatures, and in a less time than is the case with soft cheeses. The curd is subsequently warmed by heating it above the coagulation temperature. This subsequent warming is generally carried out by warming the entire mass of the curd in a kettle, with constant stirring. Occasionally, however, when in a fine condition, the curd has hot whey or hot water poured over it. It is not necessary to press the moulded curd; nevertheless it is generally done, since, by pressing it, the time required for the preparation of the cheese is shortened, and the process is rendered quicker. Hard cheeses, which, as a rule, are made heavier and larger than soft cheeses, ripen slowly, and are almost all adapted for keeping, and are thus admirably suited for export, even to tropical countries. Switzerland, Holland, England, and America divide between them the preparation of hard cheeses for the world's market. The simplest arrangements for the manufacture of cheese exist in Switzerland, in the preparation of the Emmenthaler, and the most inconvenient in America, in the preparation of the Cheddar cheese. In the preparation of hard cheese, the three different methods of salting are brought into operation. The steeping of the cheese in a solution of salt is chiefly practised in Holland, and salting, by strewing the salt or rubbing it into the cheese in a dry condition, is exclusively in use in Switzerland. In the preparation of a few kinds of hard cheese there is developed an abundant growth of certain kinds of fungi, which in time permeate the entire cheese mass.

1. *America.*—Cheddar.

2. *Denmark.*—Export, Gisler cheese.

3. *Germany.*—Algäuer Round, Leather, Tilsiter, Ragniter, Elbinger.

4. *England.*—Cheshire, Gloucester, Leicester, Dunlop, Cheddar, Derby, Factory, Savoury cheese, Pineapple, Roll, Stilton, Wensleydale.

5. *France.*—Ger, Septmoncel, Gérомé, Port du Salut, Gautrais, Providence, Rangiport, Bergues, Tantal.

6. *Holland.*—Edam, Kommission, Manbollen, Gouda, Friesische, Neumilch, Neu Juden, Holland Skim-milk cheese

7. *Italy.*—Parmesan, Cacio cavallo, Chiavari.

8. *Sweden.*—Farlosa, Flishult, Riseberga, Swartz, Stockhumla.

9. *Austria-Hungary.*—Battlematt, Borarlberger, Lüneburger, Güssinger.

10. *Switzerland.*—Emmenthaler, Gruyère, Spalen, Battlematt, Saanen, Wallis, Urfer, Engadine, Appenzeller, Prattigauer Pressen, Schweizer Mager, Pfister Mager, Chaschol de Chaschosia, Rheinwaldthaler.

Preparation of Cheddar Cheeses in America.—The manufacture of hard cheeses, which has developed in America from the beginning of 1860 up to the present time to an astonishing extent, is carried on according to a method which is similar in its essential characteristics to the method employed in England for the manufacture of Cheddar cheese. The American method only differs in a few points from the English one. The American Cheddar cheeses are manufactured in the large and numerous cheese factories of the United States and Canada. They are of cylindrical shape, their shape generally being such that their diameter is in the ratio of three to two approximately to their height. They vary in size. Whole milk for the most part is used in their manufacture. The Cheddar cheeses destined for export to tropical countries weigh on an average only 14 to 18 kilos. On the other hand, cheeses destined for export to Europe and for home consumpt are comparatively heavy cheeses, weighing as much as 60 or more kilos. Cheeses which on an average weigh 27 kilos., measure 35 to 40 cm. in diameter and 25 to 28 cm. in depth.

If it be desired to mix the evening's milk with the morning milk of the next day, as is often the case, it is placed in a cool bath, and is kept in continuous motion by a peculiar arrangement of tubes, through which water is constantly flowing so as to prevent creaming.

In the preparation of Cheddar cheese in America, special stress is put on the aeration of the milk after milking. A prevalent opinion is that fine cheese cannot be made from milk which has not been aerated. For aerating milk special arrangements are made. That excellent cheese can always be made from milk which has not been aerated is, however, well known. The opinion is also widely prevalent in America that fine cheeses of good keeping quality cannot be prepared from milk which has been reduced to a low temperature. On this account great care is taken not to cool the milk for the manufacture of cheese to too low a temperature, if possible not below 17° C.

The method of preparation is essentially as follows:—The evening

and morning milk is collected, and is poured into the cheese-vat. In cases where the milk, owing to the fact that the evening milk has been cooled below 17° C., appears to be still too sweet for perfect coagulation, from ·75 to 2 per cent of sour whey is added, and the milk is warmed to from 28° to 31° C., a small quantity of annatto being added and mixed into it. In about 20 minutes' time it becomes thick. The curd is then cut with American knives, and as soon as it begins to sink under the whey, it is warmed to from 37° to 39° C., and occasionally even 40° to 41° C., being at the same time stirred. As soon as the curd is reduced to pieces about the size of peas, it is allowed to stand either in a covered cheese-vat for from 1 to 1½ or even for 4 hours long under the whey, with occasional stirring, or the whey is removed and the curd cut into square pieces, and the pieces laid for a time the one on the top of the other. In every case the curd, before being taken out of the cheese-vat, must be examined to see that it has attained the proper degree of ripeness. This is ascertained with the hot iron. The stronger the degree of sourness in the milk before coagulation, and the quicker the curd is brought up to the prescribed temperature in the subsequent warming, the shorter will be the time required for the curd to ripen. If ripening has taken place under the whey, the use of the curd-mill is often dispensed with, otherwise the curd is always ground in the curd-mill. After salt has been added to the ripe curd in the proportion of from 1·75 per cent to 2 per cent, and in the proportion of ·33 per cent to the milk originally used, the cheese is brought into a tin cheese-mould, placed under the cheese-press, and covered over with a cloth, care being taken that the temperature is not lower than 15° C. At first the pressure applied is slight, but it is gradually increased more and more. It is calculated that the pressure on 1 kilo. of cheese would amount at most to from 7 to 9 kilos. After two to three hours the cheese is taken out of the press, the edges are cut, and it is sewn up in broad stripes of white cotton, the edges of which overlap the edges of both ends of the cheese by 2·5 to 5 cm., and they are then firmly stitched on both sides with thread. The cheeses are then brought into the press again, and allowed to remain till the following day. They are subsequently brought from the press into the store, and after their covering is taken off they are rubbed with hot melted butter, in which annatto has been dissolved. The next day they are marked with a number and a statement of their weight, and, according to necessity, for a month or even longer they are frequently brushed and oiled. In order to ripen a cheese in from 1 to 1½ months, the temperature of the store must be kept at 24°C. At a lower temperature (18°C.) cheese is ripened more slowly, but it is better. According to Curtis, the Cheddar cheeses were formerly kept too dry. Now even a slight growth of fungus on their surface is permitted. As suitable temperatures for the ripening of heavy cheeses,

18° to 20° C. may be mentioned; for cheeses of average weight, prepared from weak rennet, 21° to 24° C.; and for skim-milk cheeses prepared from strong rennet 24° to 27° C. 100 kilos. of milk will yield from 9 to 10 kilos. of fresh fatty Cheddar cheese.

Fatty American Cheddar cheeses should possess a uniform firm appearance. They should, however, be capable of being bent, and should possess a fine pure flavour and a good cheese smell. The cheese will be of an open character, that is, possessing holes, if the temperature of the air in the ripening-room be too high and the ripening process be allowed to go on too quickly.

According to the investigations of Arnold, the general opinion at present prevalent in America is that Cheddar cheeses will ripen more quickly the more rennet is added to the milk to thicken it, but that where little rennet is used cheeses of a better keeping quality are obtained. The souring to which the curd is submitted to in the cheese-vat is said to retain the animal smell of the milk, and to overcome the disadvantages which possibly arise from a long keeping of the milk before making it into cheese, and to considerably hasten the ripening process. If the milk manifest any fault, as, for example, if it possess a strange flavour and smell, or if the animal smell become strongly pronounced, or if the milk coagulate without having been previously strongly soured before thickening, the only method of obtaining good cheese in such a case is by quickly separating the whey from the curd, and by warming it to about 38° C., or by allowing the curd to remain under the whey until strong souring sets in. In this case it is recommended that strong malt vinegar be mixed with the whey in the proportion of 1 to 1000. In order to obtain good cheese from milk which has been already comparatively strongly soured, the milk should be thickened at a somewhat low temperature, namely at 25° to 27° C. More rennet should be added, so that the rennet action predominates, the curd should be cut as quickly as possible, and the subsequent warming only carried on to from 27° to 33° C. When great haste is desirable, this should be effected by the addition of a quantity of hot water. In the preparation of winter or fodder cheese, in order to hasten the ripening where the temperature is low, but where a large quantity of rennet has been added for thickening purposes, the curd should be kept for a longer period in the cheese-vat, and a uniform temperature of 24° to 27° C. should be maintained in the ripening-room.

Lately much cheese has been made in America by the American Cheddar process from milk more or less creamed, or from skim-milk, the result being that the reputation of the American cheese manufacture has been considerably lowered. In the manufacture of such cheeses, it is to be recommended, in order to assist the action of the rennet, and to hasten

ripening, to coagulate butter milk along with the creamed milk, and to coagulate at a temperature of 26° to 27° C. More rennet than is used in the manufacture of fatty cheeses should be added, in order to reduce the curd to a finer state, and subsequently it should be submitted to a more moderate warming. Skim-milk cheese should also receive more salt than fat cheese, and should be allowed to ripen at a temperature of at least 24° C. Elsworth recommends a special method of treatment of Cheddar and skim-milk cheeses. The milk is heated to from 57° to 58° C., and is then cooled to 15° or 16° C., poured into the cream vessel, and after the lapse of thirty-six to forty hours it is creamed. The cream is churned in a sweet condition, a portion of sweet butter-milk is added to the skim-milk, and the whole is treated as in the preparation of fatty cheeses. By the previous warming, as well as the addition of butter-milk, the ripening of cheese is said to be hastened.

The proper so-called "ripeness" of the curd is said to exert an influence on the cheese. If the curd be made into cheese when it is not sufficiently sour, the result is, it is asserted, that a soft cheese is obtained, which is liable to rapid decomposition, and which, it is true, quickly becomes marketable, but never gains a fine flavour such as cheese has, the curd of which has been kept for a long time in the cheese-vat, and has been subjected to souring in the proper manner. A dry crumbling cheese is obtained from cheese which has been too strongly soured.

The Preparation of Cheddar Cheese in England.—This cheese is made extensively in the western counties of England, where the art of cheese-making was already considerably developed at the beginning of this century. It is made from a mixture of morning's and evening's milk. The cheeses are cylindrical in shape, 27 kilos. in weight, on an average, and are about 27 cms. deep, with a diameter of 36 cms. The heaviest cheeses weigh up to 50 kilos., while the lightest only weigh from 8 to 10 kilos.

The preparation is carried on as follows:—The milk is first coloured with annatto, and often indeed with the juice of carrots or marigolds. It is allowed to thicken, at from 27° to 32° C., in from 60 to 75 minutes. The curd is then broken up with the ordinary cheese-knives. The milk is previously warmed in round cheese-vats, made of oak, by adding a portion of strongly-heated milk to the rest of the unwarmed milk, or by the addition of hot water to the milk. In the preparation of cheeses of 27 kilos. in weight, the cutting up of the curd occupies about 20 to 25 minutes. Before the separate pieces of the curd are reduced to the proper size, they are left for fifteen minutes in the covered cheese-vat, a portion of the whey is then removed, and the work of breaking up the curd is finished. After this the whey is all removed, with the exception of a very small quantity, and the curd is drawn together and covered over with

perforated boards which are weighted with 15 kilos. When it is observed that no more of the whey is driven out in this way, it is removed, and the board is weighted with 30 kilos. The mass of curd after a short time is broken up, either with the hand or with the curd-mill, and then submitted for some time to a pressure of from 50 to 60 kilos., 2·5 to 3 per cent of salt being then worked into it. The curd-mass is finally sewn up in cloth, and is placed in a round chest of wood or tin, with perforated sides, and put under the press. Long iron or wooden pegs are stuck through the holes of the mould, in order to facilitate the removal of the whey during pressure. After a short time the cheese is removed from the mould, is broken up and put into a fresh cloth, and again pressed for a short time. This treatment is repeated several times, till finally the cheese is allowed to remain in the press, under great pressure, for several days. In the meantime it is turned repeatedly, and care is taken that the whey flows from the mould. The pressure is increased to such an extent that it finally amounts to 30 kilos. per kilo. of cheese. After the pressure has been finished, the cheese is taken out of the mould, divested of its cheese-cloth, brought into the store, and treated in such a way that a hard rind is imparted to it. This is done by allowing it to remain for several days in a brine solution, or by rubbing salt into it. The cheeses which have salt rubbed into them, especially if they be very fat, are sewed up in linen, so that their shape may not be lost. As soon as the rind has been made sufficiently firm by the action of the salt, the cheese is dipped for a moment in warm water or warm whey. It is then dried and put in the ripening-room, where it is turned daily until it has become perfectly dry. When it has become dry, it is turned in summer three times and in winter twice a week. From time to time it is rubbed with butter. At an average temperature (15° C.) Cheddar cheese ripens so as to be ready for sale in from three to four months. Cheese of an average size of 27 kilos. do not attain their highest perfection till from six to ten months have elapsed. Large cheeses require nearly two years before they are ripened. In the store the Cheddar cheese loses in the course of a year about 15 per cent of its weight. Those cheeses which are most highly prized, and which are exported in quantity, possess a firm wax-like appearance, but are at the same time porous. When ripe in the inside, as well as near the rind, a small bright green development of mould may be observed. Cheddar cheese are imitated, especially in Holland and America, as well as in Sweden. 100 kilos. of milk yield on an average 9 to 11 kilos. of fresh fatty Cheddar cheese.

The Preparation of Edam Cheese in Holland.—The Edam cheeses (cats' heads, *tetes de maure* in France) are chiefly made in North Holland, and are placed on the market in large quantities from the town of Edam, which

lies 19 kilometres N.E. of Amsterdam. They are fat round cheeses, and weigh usually 2 to 4 kilos., and have a diameter of 11 to 15 cms. The cheeses are very seldom made larger or heavier. The heaviest cheeses weigh about 12 kilos. each. Those prepared in the neighbourhood of Hoorn are considered the finest. Those which are prepared in the neighbourhood of Beemster Alkmaar are also highly prized, and are only very slightly inferior to the cheeses which come from Edam. The small so-called "präsent" cheeses are the finest quality prepared. The smaller cheeses are divided into May cheese, 2 to 5 kilos., Summer cheese, 1·5 to 2 kilos., and Autumn cheese, 2 kilos. The Edam cheeses form a very important article of export from Holland, and find their way as far as tropical countries, like China and Australia. They keep for several years. As a rule, those destined for export are coloured externally a glittering red; occasionally also yellow, and sometimes partially red and blue in alternate segments.

The milk is placed in a wooden vessel, at 32° to 34° C. in summer, and in winter at 34° to 36° C., and thickened in eight to fifteen minutes. Along with the milk a small quantity of annatto colouring matter is put in. The curd is very carefully broken, so that no loss can take place in the fat. The breaking of the curd ought to occupy from four to seven minutes' time. (This statement, as well as those following, is based on the assumption that from 100 to 150 kilos. of milk are being treated.) After the breaking the curd is left for two or three minutes, is drawn together from the bottom of the vat by means of a wooden bowl with hollowed surface, the bulk of the whey is removed, and is pressed into the vat four times in such a way that the bowl rests on the curd with a weight of 10 to 20 kilos. After pressure has been continued for four or five minutes, the whey which flows out is removed. When this operation, which should last, on the whole, from fifteen to sixteen minutes, is finished, the temperature of the curd should be in winter at the lowest, 28° C., and in summer at the highest 32° C. If the curd has not the proper temperature, that should be imparted to it by pouring over it whey or water of a suitable temperature. The curd, when brought to the proper temperature, is removed from the cheese-vat into wooden moulds, strongly pressed with the hand, and turned two or three times. Care should be taken that the holes for permitting the outflow of the whey are not choked up. In order to prevent the cheese mass cooling too quickly during moulding, this operation should not occupy at the most more than four or five minutes time. In summer the precaution should be taken, in filling the mould, of adding a small quantity of salt in the middle of the cheese, or treating the curd, before it is put into the moulds, with a little salt water. As soon as the cheese has become sufficiently firmly pressed, it is removed from the mould, and kept for one or two minutes in a bath of whey, which

in summer is kept at 52° C., and in winter at 55° C. The cheese is then removed back from this vat into the mould. It is again pressed for two minutes more with the hands, removed from the mould, wrapped up in a piece of linen, and put back into the mould, which is then covered with its cover and placed in the press, where it is kept for a period varying according to the time of year, and to the keeping qualities which it is desired to impart to the cheese. Ordinary cheese is pressed in winter for one or two hours only, in summer, on the other hand, for six or seven hours, and cheese destined for export is pressed for twelve hours. When the cheese has been removed both from the mould and the press, it is placed, after being divested of the linen around it, in another shallower wooden mould, which is so arranged that the cheese is rounded more on the one side than on the other, and, on the other hand, is also held firmly, so that it may not roll. In these latter moulds the cheeses are placed beside each other in a comparatively deep square wooden box provided with a lid, the floor of which is slightly rounded, and provided at its deepest place with a hole for the outlet of the whey and the brine, and on the first day, above each cheese, a little salt is spread. On the second day the cheese is dipped in damp salt, so that the whole surface of the cheese is covered with salt. It is then returned to the mould, where it is placed in such a way that the portion which was first uppermost is now undermost. In this way salting is continued for nine or ten days, until the cheese is completely saturated with salt, and is no longer elastic, but quite hard to the touch. Finally, the cheese is laid for some hours in the brine which has been collected, washed with water, dried, and placed on a wooden stand in a dry, well-aired store-room, in which the temperature of the air is not allowed to fall below 6° C., and not to rise above 22° C. In many cheese factories the cumbersome method, above described, is dispensed with, and the cheese is placed directly in strong brine. The airing of the store-room should be supervised with the greatest care, and must be discontinued in very dry as well as in foggy or damp weather. If the store-room be too damp, the cheese becomes covered over with a blue or yellowish mould, and depreciates in quality. During the first month the cheese is turned daily, and during the second twice a day, and subsequently only twice a week. As soon as the cheese is a month old it again undergoes special treatment. It is softened for an hour in water warmed to 20° to 25° C., then brushed with a brush, dried for from twenty to forty minutes in the sun, and returned to the store-room. After the lapse of fourteen days this treatment is repeated, and the cheese is rubbed with linseed oil. It is common in Holland to sell cheeses only six weeks old to the dealers, who themselves submit the cheese to the subsequent treatment. Cheeses destined for export are scraped with a sharp knife or special machine before being sent

away, so that they may have as smooth a surface as possible. They are then coloured according to their destination. Cheeses which are not destined to be sent far, are either not coloured at all, when they are put on the market as white cheese, or they are coloured with colcothar. Cheeses destined for export are usually coloured with a substance which consists of 36 per cent of turnesol (*Crozophora tinctoria*), 3 per cent of Berlin red, and 61 per cent of water. 16·5 kilos. of this mixture, costing about nine to ten marks, is sufficient to colour 1000 cheeses. The cheese is painted with this mixture, allowed to become dry, and then rubbed off with a little butter, which is slightly coloured with Berlin red. The cheeses are finally packed in boxes side by side, separated by small boards, or wrapped up in animal bladders. The cheeses with red rinds are known as red-crusts. Simpler but less appetizing is the practice of colouring the cheese red with woven cloth coloured red with the juice of turnesol. The cheeses destined for England and Spain are coloured yellow, the colour being imparted by a solution of annatto in linseed-oil.

From 100 kilos. of milk 10 to 11 kilos. of fresh and 8 to 9 kilos. of saleable Edam cheese is obtained. Whey butter is prepared from the whey.

Good Edam cheese becomes covered over in time with a thin dry bluish green efflorescence. In addition to the fact that the cheese becomes puffy or oily and cracked, it is often flecked with blue patches. A curious fault of this cheese consists in the fact that, even where the rind is perfectly sound, internal fissures are to be found in the inside of the cheese, so sharply cut that they look as if they had been cut with a knife. In cheese where this is the case, either in course of time putrefactive decomposition takes place, or the rind sinks over the fissure and forms homes for the growth of moulds. Too damp an atmosphere, and, still more, dry cold winds, are hurtful to the cheeses in the store. In the preparation of Edam cheese, it is not considered advisable to use the milk of newly-calved cows before the ninth day. Milk very rich in fat is not so suitable for the preparation of Edam cheese. Edam cheese which has gone bad is pounded into barrels, and the mass is sold as *pottkaas*.

The Preparation of Emmenthaler Cheese in Switzerland.—Emmenthaler cheese, the best and most famous of Swiss cheeses, is chiefly manufactured in the Canton of Berne. The Emmenthaler cheeses are made from whole milk, or a mixture of whole milk and slightly skimmed milk, and are exported to all parts of the world, especially to Germany, Austria, Russia, France, and North America. In North Germany they are known as "thränen" cheeses, and in France they are known under the name that is applied to all Swiss fatty hard cheeses, namely Gruyère. They possess the shape of mill-stones, and weigh nearly 50 to 65 kg., with a diameter

of 70 to 80 cm., and a height of 10 to 13 cm. In certain districts cheeses even heavier and larger are made, possessing a weight of 100 to 125 kg. or even more. In the author's opinion, the Emmenthaler is the finest and the best of all the rennet cheeses, and requires for its preparation more knowledge in the art of cheese-making, and more skill and practice, than does the preparation of any other kind of cheese.

In the preparation of fat cheeses, the morning's milk is warmed in copper kettles to 40° to 42° C. The evening's milk of the previous day is creamed in the meantime, and the cream added to the warm morning milk, and thoroughly mixed therewith, which is easily effected owing to its temperature. The cooled evening milk, which has been thus skimmed, is then added to it, thoroughly mixed with it, and the temperature of the liquid, according to the time of the year and other conditions, raised to 33° to 35° C. It is then coagulated in 20 to 35 minutes. During the thickening, the cheese-kettle is covered if necessary. Along with the rennet is added a small portion of cheese saffron, which is mixed previously with a small quantity of milk. It is better to add an exactly measured quantity of saffron solution proportional to the quantity of milk to be coloured. As soon as the curd has obtained the proper firmness, it is cut with the cheese-knife crosswise into pieces of a parallelepiped shape, and the whole mass is turned in the kettle with the scoop, so that the lowermost portions are brought to the surface. It is cut at the same time into pieces about the size of one's hand, and stirred with stirring-sticks until they are the size of peas. This operation occupies about 25 minutes. The curd is then allowed to stand for a moment, and 25 per cent of the whey is removed into a tub prepared for the purpose. It is then again stirred and the warming continued. The temperature during this continued stirring is gradually raised to 56° to 58° C., and the stirring is still continued, until the curd, which is frequently tested, has gained the desired firmness and elasticity. As warming and stirring occupy 35 minutes, the entire treatment of the curd in the kettle takes on the whole about 60 minutes. After the stirring has been finished, a portion of the hot whey is removed into a special vessel, and poured into the kettle among the whey which has been previously removed, in order to lower the temperature of the contents of the kettle, so that when the curd is removed the arms may not be burnt. The entire mass of curd is then lifted by means of a wooden hook and a cheese-cloth, and placed in the mould-hoop between box covers under the press. Here the cheese remains for 24 hours, and during this time it is turned in all 7 or 8 times, for the first time after some 15 minutes from the time the cheese has entered the press, and 30 minutes later, and again after an hour, and from then on at intervals of rapidly increasing length. At every turning the cheese-cloth is removed,

and the mould-hoop if necessary is made narrower. If, owing to the pressure, small protuberances of cheese are formed on the top and bottom of the hoop, these should be cut off with a short knife at the third turning. At first the cheese is submitted to a weak pressure, which is gradually increased, and which after 8 hours is rapidly increased, viz. 8 to 10 kg. for a cheese of 30 kg., and 14 to 16 for a cheese of 50 kg. on every kilogram of cheese. For pressing cheese the Swiss lever presses are used. After the whey which has been drained off has been put back into the kettle, the next process is to separate the whey cream. The temperature is slowly raised at first until it has reached 68° to 70° C. One part of strongly-soured whey is then added for every 100 parts of milk to be treated. The temperature is then increased to from 80° to 95° C., and the froth, which in the meantime is separated from the clear whey, is skimmed off. The quantity of whey cream amounts on an average to from 3 to 4·5 per cent of the milk treated. After standing for 24 hours and churning in the ordinary method, ·75 kg. of whey cream butter should be obtained for every 100 kg. of milk. As soon as the whey cream has been skimmed off, one to three—on an average two parts—of sour whey is added to 100 parts of the milk to be treated, and the whole is slowly warmed until the whey at the bottom of the kettle begins to boil, and the *Ziger*, known also as Bavarian Algäu (*i.e.* the albuminoid matter remaining in the whey), comes to the surface, and is separated out in the form of large porous pieces of a yellowish colour. Occasionally it happens that the *ziger* does not come to the surface. In such a case the manufacturer effects this by placing a wooden milk-bowl on the whey, and allowing it to float. Thereupon the liquid immediately below the bowl sinks, since it is rapidly cooled, and causes currents to take place in the milk which bring the *ziger* to the top. After the *ziger* has been scooped off by means of a perforated tin ladle, the entire milk utensils, including the churn, are cleaned with the whey remaining behind. For every 100 kg. of milk treated, there is obtained, on an average, from 7 to 8 kg. of fresh *ziger*. If, on the other hand, the *ziger* is weighed only after it has been made into cheese, and submitted to strong pressure for 24 hours, it will be found that only 2 to 3 kg. of fresh *ziger* cheese is obtained for 100 kg. of milk treated. *Ziger* cheese is only made to a small extent. Since fresh *ziger*, when eaten along with salt and potatoes, furnishes a pleasant and nourishing food, it is in some parts regularly used as an article of diet. It is chiefly used, however, along with whey, for feeding calves, especially bull calves, and pigs. When pigs are fed with *ziger* and whey, it has often been noticed that where they receive no other food except butter-milk a breeding sow may be fed on the milk of 4 to 6 cows. In some parts of the Alps the experiment has been made of utilizing whey as a manure, just in the same way as urine is used.

This method of utilizing whey, however, is not to be commended. In the cantons of Berne and Lucerne in the Alps, the so-called sugar-sand is obtained in summer from the raw milk-sugar of the whey. Occasionally —that is about once or twice during the period of mountain pasturing— the cow-keepers boil the whey and prepare *molkensich*, a substance made out of the solid constituents of the whey. It consists mostly of sugar, is of a chocolate-brown colour, and is shaped in the form of a brick. It is used for eating with bread-and-butter on festive occasions.

The soured whey, the sourer which is used to separate out the whey cream and the *ziger*, is put in the sourer barrel, which is placed in a warm part of the cheese-store, usually near the fireplace of the cheese-kettle. It is made of wood and of a conical shape, and of from 75 to 100 litres capacity. This barrel is covered with a wooden lid and fitted underneath with a cock, and is not allowed to become empty during an entire period. It is at first filled with whey, which rapidly sours, owing to the warm place in which the barrel is kept. The whey required is daily tapped off, and the space filled up again immediately with sweet whey. The strength of the sourer determines the quantity to be used. If at the beginning of the period of mountain pasturing no sourer is obtainable, diluted vinegar is employed.

After the cheese has been taken out of the press, it is numbered with ink, or with a black colouring matter prepared from lamp-black and oil, and is brought into an airy room, where it is allowed to remain for 24 hours, generally as it is, occasionally in a mould-hoop. It is thereafter brought into the cheese-cellar and treated with dried salt. During the first weeks the cheese is provided with cheese-binders similar to mould-hoops, but made of soft wood. The mode of salting, as well as the different precautions which have to be carried out in salting this cheese, have already been pointed out and discussed in § 115, and the requirements which are necessary for a good cheese-cellar as well as the temperature and moisture most suitable for the storing of cheese, have already been discussed in § 116. About 20 days after the cheese has been brought into the cellar, often indeed sooner—sometimes as soon as it has been brought under the press—the formation of the large eyes in the cheese begins to take place. Before cheeses of 50 kg. and above that weight have become perfectly ripe, and have attained their full taste, 8 to 12 months must at least elapse, during which time the cheeses on an average lose about 12 per cent of their weight. For salting, on an average, during the first two months, 2 kg. of salt are required per 100 kg. of cheese, and the loss in weight in this time amounts to from 6 to 7 per cent. In the preparation of fatty cheeses, 100 kg. of milk yield in summer on the Alps 9 to 11 kg. of Emmenthaler cheese, in summer in the valley dairies, 8 to 10 kg., and

in winter 7 to 9 kg. In the preparation of half fatty cheeses, there is obtained per 100 kg. of milk on the Alps 9 to 10 kg. of cheese, and in the valley dairies 8 to 9, and in winter 7 to 8 kg. It is calculated that in the preparation of half fatty cheeses, that is, cheeses made from morning milk and skimmed evening milk of the previous day, from every 100 kg. of fresh cheese there are made in summer 14 to 16 kg. of butter, and 13 to 15 in winter; and each additional kg. of fat in the cheese increases or diminishes the weight of the cheese by 1·5 kg.

Good Emmenthaler cheese of the best quality should possess a mild, piquant, nutty flavour, and should be free from fissures or cracks. On a fresh-cut surface the eyes, namely, the single large circular openings which distinguish this cheese from all other cheeses, should be uniformly placed in the cheeses, and should appear of a uniform size. The distance between the different eyes should be 4 to 6 cms. The internal portion of the eyes, which varies from 6 to 10 mms., on an average 8 mms., should possess a dull glitter, but should be free from small drops of liquid. The Emmenthaler cheeses which have not been successfully manufactured are divided, according to the more commonly occurring faults, into *Geblähte Kase*, *Niszler*, and *Gläsler*.

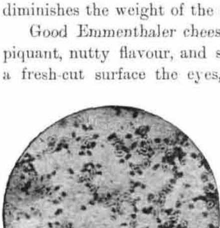


Fig. 75 —*Bacillus diatrypeticus casei.* Enlarged 850 times.

Our information with regard to these faults is based upon the observations and opinions of cheese manufacturers. Scientific opinion and research have only been very recently undertaken on the subject. According to the practical man, the explanation of the proper course of ripening, and the explanation of the faults to which the cheeses are liable, are extremely complicated. This is no doubt true, but not to the extent which is believed.

So far as our knowledge at present extends, the most of the processes in operation on the ripening of cheese are caused by fission fungi, and it is certain that in the peculiar ripening process going on in the Emmenthaler cheese, certain gas-generating bacteria, in addition to many other kinds of bacteria with other properties, exercise an important function. To these gas-generating bacteria belong the bacillus depicted in the accompanying diagram (fig. 77). The lactic bacteria are agents exercising a secondary influence. The action of the gas-generating bacteria should neither begin too early nor go on too long for the cheese to attain its proper condition. It should go on exactly at the time that the cheese mass has attained a certain amount of firmness and mobility, in an even manner,

and should not be interrupted. Certain gas-generating bacteria, which are always present in the byre, in the food, in the udder of the cow, and in dairies, occasionally in enormous quantities, should not be wanting in milk which has to be made into cheese, but they should not be permitted to choke out other kinds of bacteria.

Lately it has been discovered that the preparation of Emmenthaler cheese is facilitated if the milk which has to be treated possess a certain definite degree of sourness, neither too strong nor too weak, and that it is desirable where this sourness is lacking to increase it by the addition of sour whey. The quantity of lactic ferment which, as experience has taught, produces the proper degree of sourness, seems to regulate in a beneficial manner the growth of the gas-producing bacteria, by limiting them when they are in excessive quantity, but not exercising an unfavourable influence when they are present in small quantity. If the manufacture of the cheese gains in security by the addition of small quantities of sour whey to the milk, it loses on the other hand, it would appear, in fineness of flavour.

Puffy cheeses have irregularly distributed cavities as large as the fist, and exhibit a more or less disfigured external appearance, assuming in the course of time a peculiar soapy flavour. Very often the swelling of the cheese begins on the surface; and often a few hours after the preparation of the cheese it becomes puffy, when the ordinary gas-forming bacteria choke out the other bacteria, or when strange ferments are present which give rise to a fermentation in which there is a development of gas. This occurs most frequently where the milk to be treated is dirtily handled, and feeding-stuffs have been used which contain such fungi. Puffiness is favoured by faults in the preparation and treatment of cheese, which result in too much moisture remaining behind in the cheese mass, such as using too weak rennet, thickening at too low a temperature, insufficient stirring, too quick warming, careless straining of the curd, insufficient pressure, carelessness in pressing, unskilful salting, and too high a temperature in the air of the store-room. Puffiness in the cheese, in the opinion of the author, is in most cases caused by fission fungi, and not by budding fungi. The gases produced in puffiness, in addition to carbonic anhydride, are large quantities of hydrogen.

122. Rennet Cheese from Sheep's Milk. — Cheese from sheep's milk is prepared wherever sheep are kept on a large scale. It is made in small quantities, and for consumption in the neighbourhood of the place of manufacture. Only one kind of cheese made from sheep's milk, viz. the famous Roquefort cheese, made in France, is placed on the world's market.

The following is a list of cheeses made from sheep's milk in different countries:—

1. *Germany.*—Mecklenburg.

2. *France.*—Roquefort.

3. *Holland.*—Tereler.

4. *Italy.*—Formaggio fresco di pecora detto cacio fiore, Formaggio dolce di pecora, Formaggio detto da taglia grosso, Formaggio di pecora merina, Formaggio di pecora da Serbare, Formaggio delle crete Senisi, Formaggio di pecora detto cacio fiore di Viterbo, Formaggio di pecora di Lionessa, Cacio di Puglia, Marzolino, Tratturo, Formaggio all uso Parmigiano, Formaggio di Catrone, Ancona Skim-milk, Scanno Skim-milk, Iglesias Skim-milk cheese.

5. *Austro-Hungary.*—Brinsen, Laudock, Zipser, Liptauer, Siebenberg, Neusoler and Altsoler Carpathian, Kascaval, Kolos monostor, Klenoczer, Abertamer.

Preparation of Roquefort Cheese in France.—The celebrated Roquefort cheeses, which form extremely fine-flavoured table cheeses, are made from sheep's milk. They are made from a mixture of whole milk and partially skimmed milk. In form they are cylindrical, and in a fresh condition are 18 cms. in diameter, 8 cms. deep, and on an average 2·15 kilos. heavy. In the ripened cheese they are 17 cms. in diameter, 7·5 cms. deep, and on an average 2 kilos. in weight. Good ripened Roquefort cheeses are neither soft nor oily, but are friable in appearance, and are permeated with grayish green patches of fungoid growth. The preparation of Roquefort cheese, which was formerly made from a mixture of sheep's and goats' milk, is very old—indeed, it is known that it was practised in the caves of Roquefort as early as the year 1070. The preparation of this cheese was formerly confined to the neighbourhood of the village of Roquefort, in the Department of Aveyron, on the river Soubzon; but it has now spread over the entire arrondissement of St. Affrique and of Milhau, over a portion of the arrondissement Lodéve (Department Herault), over the cantons of Canourgue (Department Lozere), and of Treves (Department Gard), as well as over the single canton of the Department Tarne. Roquefort cheeses seem to owe their peculiar properties partly to the naturally cool and continuous currents of air passing through the rock caves in which the ripening is carried on. These caves are situated in the narrow, flat mountain passes which run between St. Affrique and St. Rome de Cernon on the east, and to the north side of the tableland of Larzac, and are chiefly cut out of the Jurassic chalk.

The milk used for the preparation of Roquefort cheeses is obtained from Larzac sheep, which are milked twice a day. The evening milk

has its froth first removed, and is allowed to stand for three-quarters of an hour, when it is heated in a galvanized copper vessel almost to boiling, cooled down, and kept overnight in glazed clay bowls. On the following morning the cream is removed in order to be subsequently churned, and the morning milk is added to the skim-milk, and thickened at 33° to 35° C. with rennet. The curd is carefully broken up and the whey removed. Each piece of the curd is pressed carefully in order to remove as much of the whey as possible, and placed in cylindrical moulds made out of strongly burnt glazed clay, which are 21 cms. broad and 9 cms. deep, and in the bottom of which there are round holes ·5 to ·6 cm. broad. This is done in such a manner that the curd is placed in the moulds in three equally thick layers, between every two of which a layer of firmly baked cake of powdered mouldy bread is placed. This is most suitably made out of equal parts of wheat and barley-meal, with the addition of sour paste and strong vinegar. For every 100 parts of paste there should be 4 to 4·5 parts sour paste and ·05 parts of vinegar. The fresh baked bread is allowed to become mouldy, and the mouldy crumbs, cut off it and ground in a hand-mill, are pressed through a sieve. In this way, by adding this powder to the curd, the spores of the moulds are conveyed into it, and under their action the ripening process of the cheese is effected. Boards are laid upon the raised surface of the curd mass in the mould. These are at first slightly weighted, subsequently more heavily, and then pressed from 10 to 12 hours in this way, the cheese being repeatedly turned. After the pressing operation has been finished, the cheese is removed from the mould, and allowed to lie for 10 to 12 days wrapped up in cloth. They are turned twice a day, the cloth being often renewed, and finally, after the cloth has been taken off, drying is promoted by a dry current of air. The cheeses are then brought carefully from the drying-room during the night-time into the rocky caves, each of which is divided into three compartments—the so-called grotto (*la cave*) in which the cheese is allowed to ripen, the salting-room (*le saloire*), and the weighing-room (*le poids*). The two last mentioned rooms are situated above the grotto. After the damaged cheeses have been separated out in the weighing-room, which also serves as a receiving-room, the other cheeses are laid upon a straw-covered floor. They are allowed to stand for 12 hours, from morning till evening, and are then brought into the salting-room. Here the cheeses are strewn with fine salt on the one side. They are placed three deep, and turned after 24 hours, when they are salted on the other side and again piled up as before. After the lapse of 48 hours the salt is rubbed into the cheese on all sides with a coarse linen cloth, and the cheeses are then left again, piled three deep, for another three days. At the end of this time they are brought back into the weighing-room,

where they are submitted to a somewhat laborious cleansing (*le reclage*), *i.e.* they are scraped twice with sharp knives. The material which is first scraped off, which is known as "*pegot*", is used as food for pigs, and what is subsequently scraped off, and which is known as "*ribarbe blanche*", is sold at 32 to 40 pfennig per kilo. After the scraping operation is finished, it is possible to judge of the individual excellence of the cheeses. They are separated according to quality into three classes, and are placed three deep in the grotto, the hardest cheeses being placed on the straw-covered floor, while the others are placed upon wooden stands arranged round the walls and in the middle of the room, and provided with straw. In the grottoes, into which cold air is constantly passing through numerous clefts, the temperature of the atmosphere varies throughout the whole year between 4° and 8° C. The air contains only about 60 per cent of its average moisture. Eight days after the cheeses have been removed to the grotto, they are placed on their sides, in order to promote the circulation of air over their surface. The cheeses are covered during the ripening at first with a reddish or yellowish crust, on which is developed, subsequently, a thick white substance. As soon as the covering of mould has reached a thickness of 5 to 6 cms. the cheeses are again scraped, this scraping (*le revirage*) being repeated at intervals of from 8 to 14 days, until the cheeses become ripe and are removed from the grotto. The scrapings (*reverum*) are used for feeding pigs. During the whole process, from the time the fresh cheese is brought into the cave, up to the time it is ready for the market, it loses 28 to 30 per cent in weight, and the loss of weight due to repeated scraping in the grotto amounts to 23 to 25 per cent. The cheeses which are prepared during the early months of the year should become ripe and ready for sale in 30 to 40 days, and those made later in a somewhat longer period. 100 kilos. of milk yield 18 kilos. of fresh cheese ready for salting, and 12 to 14½ kilos. ready for the market.

The treatment of Roquefort cheeses in grottoes, which up to 1873 was almost exclusively effected in a clumsy way by hand-labour, was very much improved in the year 1874 by the director of the United Cellar Company, who introduced two special machines driven by steam, which thus replaced to a certain extent the slow and laborious methods previously employed. One of these machines was the brushing machine, which effects the scraping of the cheese, and which can be worked by two women. The cheese are brought at first between two circular-shaped horizontal brushes, which clean the bottom and the top of the cheese, and then between vertical brushes, which clean the sides of the cheeses. They are so constructed that they can clean per hour 4800 cheeses, or as many as could be undertaken in the same time with difficulty by 20 women. At the same time the machine only causes a loss of 10 per cent, instead of 23

to 25 per cent. The other machine is the Prickel machine, and can also be worked by two women. It pierces through, with a wheel provided with 60 to 100 very fine comparatively long needles, 10 to 12 cheeses every minute. Although the cheese mass is inoculated with large numbers of fungoid spores, it is found that the development of moulds in the interior of the cheese at the temperature prevailing in the grotto is not as rapid as desirable. As the fungi in the interior of the cheese develop more rapidly the more air is admitted, this is effected by pricking the cheese with needles, and an increased development of fungi is obtained.

The cheeses most prized are those made in the grottoes during the months of May and June, which are ready for sale from September to December. They are packed in cylindrical baskets, in wooden baskets, gagets, and in boxes. Between each cheese thin pieces of wood are placed. The finest cheeses are wrapped up in tin-foil. Roquefort cheeses are exported to all parts of Europe, to America, to the colonies, and to China. The finest, and at the same time, those possessing the best keeping qualities, are called Crème de Roquefort. In the districts surrounding Roquefort, cheese is made from cows'-milk after the Roquefort method.

123. Rennet Cheeses made from Goats' Buffalo, and Reindeer Milk, and also from Mixed Milk.—The cheeses made from this group are of little importance, as they are only manufactured in small quantities, and for immediate use in the neighbourhood of the place of manufacture. They are as follows:—

1. *Germany.* — Ziegenkäse des Riesengebirges, Altenburger Ziegenkäse.
2. *France.*—Mont d'Or, St. Claude, Gratairons, Chevretins, St. Marcellin, Sassenage, Septmoncel, Mont Cenis, Tignards, Gavots.
3. *Italy.*—Büssel, Provole, Scarmorze, Borelli.
4. *Lapland.*—Rennthier.
5. *Norway.*—Hviteost.
6. *Austro-Hungary.*—Brinsen, Arnauten.
7. *Sweden.*—Ziegen, Rennthier.
8. *Switzerland.* — Ziegen, von Graubünden, Gaiskäsli von Solothurn.

124. Sour-milk Cheese made from Cows' Milk.—Sour-milk cheeses are prepared chiefly as an article of nutriment for the poor. Only one kind, viz. the Glarner green cheese, constitutes an important article of commerce and of export. The sour-milk cheeses are generally made only from skim-milk and butter-milk. Cream, however, and even butter is often added to the curd, at the rate of 10 per cent

of its weight. The separation of the curd is effected, when the liquid has become sufficiently sour, by simply warming at 37° to 50° C., or by the addition of hot water. If the liquid be not sufficiently sour, sour butter-milk is added before warming. At temperatures under 35° C. the separation is effected very slowly and very imperfectly, and at temperatures over 50° C. the curd is found to be friable and too dry. In the preparation of sour-milk cheese, it ought not to be forgotten that the sour liquid acts upon metals, and that the cheese may become poisoned if the curd be allowed to stand for a long time in bright copper kettles. For this reason, heating should only be conducted in copper kettles plated with tin, and the curd should be brought into wooden vessels as soon as separation is effected. During the preparation of numerous kinds of sour-milk cheeses, the curd is kept for some time before moulding, and a species of fermentation is allowed to go on in it. During the ripening process, everything depends on whether moulds are kept from the cheese. 100 kilos. of skim-milk or butter-milk, or a mixture of skim-milk and butter-milk, yield, according to whether a greater or lesser amount of pressure is applied, 8 to 13 kilos.—on an average 11 kilos.—of fresh curd, and 5 to 8·5 kilos. of perfectly ripened sour-milk cheese. 100 kilos. of milk should produce 7·5 to 9·5 kilos. of fresh sour-milk cheese, in addition to 3 to 3·5 kilos. of butter. All sour-milk cheeses are salted in the vat, and many kinds have all sorts of things added to them, especially herbs (*zigerklee*). The smaller fresh sour-milk cheeses under ·3 kilo. in weight suffer a distinct loss in weight during ripening, which, when the cheese becomes slightly ripe, amounts to about 30 per cent, and when the cheese is quite ripe, to from 35 to 50 per cent or more. These small cheeses are generally

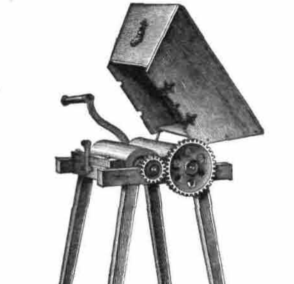


Fig 76.—Curd Mill.

sold when they begin to take on a yellowish external appearance, or when they are surrounded with a yellowish rind some millimetres thick. Many farmers do not themselves work the curd which they have prepared, but sell it to the manufacturers, who carry on the preparation of sour-milk cheeses on a large scale. The manufacture of sour-milk cheeses is carried on in Germany to the greatest extent in Hessen and Thuringia, in the Hartz, in the Riesen Gebirge, and in several districts of Westphalia. Curd presses, curd mills (figs. 76 and 77), and hand cheese moulds, machines for brushing and washing the cheese at the beginning of the ripening, are the utensils used in its manufacture. The sour-milk cheeses made in different countries are as follows:—

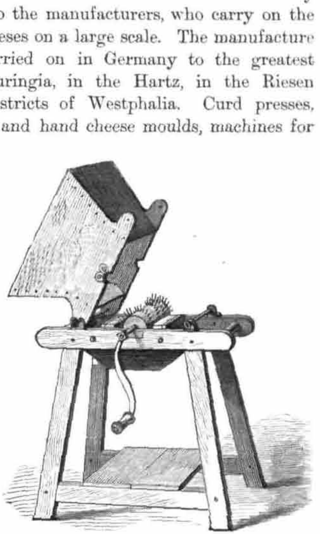


Fig. 77.—Cheshire Curd Mill.

1. *America.*—Pot, Cottage, Sour-curd, Sour-milk, Queso de quincho, Queso de palma metida, Queso de mano.

2. *Belgium.* — Belgian Sour-milk.

3. *Germany.* — Ostpreuszische Glumse, Soft-curd, Bauden, Alte Kuh, Berlin, Soft-hand, Markischer Preskase, Kinnen, Sarz, Ihleselder, Pimp, Nieheimer, Brand, Dresden, Sachsische Sour-milk, Thuringer Caraway, Hartz, Main, Caraway small cheese, Health cheese, Sour-milk, Potash.

4. *France.*—Peasant, Broccio.

5. *Italy.*—Chiavari.

6. *Austro-Hungary.*—Olmutzer Ouargeln, Borarlberger Sour-milk, Sperr, Trocken, Montavoner Krauter.

7. *Russia.*—Livlander Sour-milk, Krutt.

8. *Sweden.*—Gammelost, Pultost, Knaost.

9. *Switzerland.*—Glarner, Schabziger.

Preparation of Potato Cheeses.—The preparation of potato cheeses is only

carried out now to a very limited extent. These cheeses, which were formerly made of different shapes, were at one time popular in Thuringia and Saxony They were made by mixing certain quantities of curd with good peeled potatoes, which were pounded down and mixed in the proportion of one to one and a half parts of curd to two parts of potatoes. They were then salted and flavoured according to taste with caraway seed, well worked and laid in covered vessels, and allowed to lie for two days in summer, and after the lapse of this period they were again thoroughly worked and moulded. After two days they were placed upon stands at a gentle temperature, till they became thoroughly dry, care being taken, however, that they should not become cracked. If the cheeses became too dry they were damped with beer or sour milk. The dried cheeses were then laid in bowls with chickweed, and allowed to remain there for fourteen days. In this way the cheeses acquired a good flavour.

125. Cheese-like Products from the Refuse of Cheese Manufactories. —*From* the liquid refuse of cheese manufactories the following products may be obtained:—

Mysost.—This is obtained by treating the whey which is obtained as a bye-product in the manufacture of rennet cheese. It is much liked in the hill districts of Scandinavia. It is moulded in the form of parallelepiped-shaped pieces, possesses the colour of chocolate, has a pleasant taste, and is slightly granular and of a soft texture. It consists chiefly of milk-sugar, but contains, in addition, the albuminoid bodies present in the whey, lactic acid, some fat, and the mineral constituents of milk, less what has been taken up by the separated curd. In the manufacture of cheese from milk, 100 kilos. of milk yield on an average 3 to 3·5 kilos. of butter, 4 to 5 kilos. of fresh skim-milk cheese, and 6 to 7 kilos. of mysost.

Schottensicht, that is, the solids rising from the whey, are separated out and utilized in Switzerland as well as in the hilly districts of Germany and Austria. It is obtained by steaming the whey, and is much the same as *mysost.*

Ziger Cheese. — When the liquid residue of rennet cheese is rendered acid and is heated almost to boiling point, the albuminoid bodies which it still contains are almost entirely precipitated in large yellowish-white flocculent masses. This substance, which is known in Germany, Austria, and Switzerland as *Ziger*, in France as *Recuit*, and in Italy as *Ricotta*, is either consumed in a fresh state or worked into *ziger* cheeses. The better-known Swiss *ziger* cheeses are, for example, the Hudel-izig of the Canton Glarus, and the Mascarponis

of Bergell in the Canton Graubünden. A mixture of fresh *ziger* and cream, which is eaten in Savoy with pounded sugar as a dessert, is known in that district universally as *gruax de montagne*. From calculations made by the author, it may be reckoned that 100 kilos. of milk, in addition to the above-mentioned bye-products, will yield 7 to 8 kilos. of fresh unpressed *ziger*, or 2 to 3 kilos. of fresh pressed *ziger* cheese.

The residue from sour-milk cheese manufactories is not, as a rule, further treated. In Norway the curd whey remaining behind in the preparation of *Gammelost* and *Pultost* are here and there steamed and worked into a stiff dry pulp, and after they have cooled sufficiently are packed and sold under the name of *Surprim*.

126. The Liquid Residue of Cheese.—The liquid remaining behind in the manufacture of cheese by rennet is known as whey, and generally this word is sufficient to indicate perfectly the residue from cheese. On theoretical grounds, however, it is desirable to use two words for the purpose of distinction, viz. the words cheese-milk and whey. Whey is the name we may apply to the liquid remaining behind, after the removal of the curd from the cheese-vat, from which butter can be obtained in the form of *vorbruch*, or whey-butter (in fat cheeses and *ziger*). On the other hand, the residue which is obtained after the removal first of the *vorbruch* and then of the *ziger*, we shall call cheese-milk. The residue of sour-milk cheese may be called curd-whey or curd-serum. The composition of cheese-milk, whey, and curd-whey is, according to investigations of the author, as follows:—

	Cheese-milk.	Whey.	Curd-whey.
Water, ...	93·15	93·31	93·13
Fat, ...	0·35	0·10	0·12
Nitrogenous matter, ...	1·00	0·27	1·06
Milk-sugar and lactic acid,	4·90	5·85	4·87
Mineral matter, ...	0·60	0·47	0·82
	100·00	100·00	100·00
Nutritive ratio.	1:5·78	1:22·60	1:4·88

From the residue left over in cheese-making, milk-sugar is obtained, regarding which something will be said further on. Usually it is converted into money by feeding swine with it in the form of whey or curd-serum. If it be calculated that, on an average, according to elaborate and extensive experiments which

have been carried out on this subject, for 1 kilo. of live weight made one pfennig is expended, it may be assumed that such an estimate is not too high.

Attempts have been repeatedly made to manufacture the residue from cheese manufacture into alcohol, or vinegar, or spirituous liquors, as whey-champagne and whey-punch, as well as to use it in the baking of bread, instead of milk or skim-milk. None of these methods, however, have as yet proved themselves to be profitable.

In baths and in places where the air cure is carried out, whey is used, especially for people suffering from lung and chlorotic diseases, and convalescents, since it exercises a favourable influence on the digestion and condition of the invalid, if taken daily for some time in suitable quantity. Should it be impossible to obtain whey for this purpose from dairies, and if it be desired to prepare clear whey on a small scale, this can best be effected by adding for every kilo. of milk ·10 gram of crystallized citric acid and 1 c.c. of rennet solution of average strength, and heating to boiling, boiling for fifteen minutes, and then filtering through thick linen.

According to the few investigations which have been carried out, the ash of the whey of goats' milk has the following composition:—

Potassium chloride, ...	50·00
Sodium chloride, ...	10·00
Potassium phosphate, ...	21·00
Calcium phosphate, ...	14·00
Magnesium phosphate, ...	5·00
	100·00

The specific gravity of ordinary whey, or curd-whey, may be said to lie between 1·025 and 1·028, and that of cheese-milk between 1·027 and 1·029, at 15° C.

127. Yield of Cheese.—With regard to the use of fresh or ripe cheeses of different kinds, I have brought together in the preceding paragraphs such information as the literature of the subject affords, and as my own experience offers. In what follows I shall give, in a few figures, a comprehensive survey of the subject.

The yield of cheese from milk is, as a rule, greater in the manufacture of soft cheeses than in the manufacture of hard cheeses, and greater in the manufacture of fat cheeses than in that of skim-milk cheeses. It is high when fat cheeses, which are immediately eaten or

are for immediate use, are made. Broadly speaking, one may reckon that 100 kilos. of milk will yield—

Of soft, fresh, fat cheeses for immediate consumption, 25 to 33 kg.

Of very soft fatty cheeses (Brie and Camembert, Neufchatel, &c.), 18 to 22 kg. of fresh, or 12 to 15 kg. of ripe cheese.

Of somewhat firmer, fatty, soft cheeses (Limburg, Remoudou), 13 to 16 kg. of fresh, or 9 to 11 of ripe cheese.

Of soft half-fatty cheeses (Limburg), 1·5 kg. of butter and 12 kg. of fresh, or 9 to 11 of ripe cheese.

Of soft skim-milk cheeses (*à la* Brie, Camembert, Liverot, Backsteinkasen), 3 to 3·4 kg. of butter and 7·5 to 12 kg. of fresh, or 6·5 to 9 of ripe cheese.

Of Roquefort cheese, on an average, 18 kg. of fresh and 12 to 14·5 of ripe cheese.

Of fatty hard cheeses, made according to the American or English method, 9 to 11 kg. of fresh, or 8 to 9 kg. of ripe cheese, and ·75 kg. of butter.

Of fatty hard cheeses, made according to the Dutch or Swiss method, 8 to 11 kg. of fresh, 7 to 10 of ripe cheese, and ·75 of butter.

Of half-fatty hard cheeses, 7 to 10 kg. of fresh, 5 to 8 of ripe, and 1·6 of butter.

Of hard skim-milk cheeses, 5 to 7 kg. of fresh, or 4 to 6 kg. of ripe cheese, and 3 to 3·5 of butter.

Of fresh-pressed curd, 8 to 12·5 kg. and 3 to 3·5 kg. of butter-milk.

Of sour-milk hand cheeses, 7·5 to 9·5 kg. of fresh, or 5 to 6 kg. of ripe, and 3 to 3·5 kg. of butter.

Of Glarner Schabich, 10 kg. of fresh, or 6 to 7 of ripe cheese, and 3 to 3·5 kg. of butter.

Of Swedish and Norwegian Gammelost, 3·5 to 5·5 kg. of fresh, or 2 to 3 kg. of ripe cheese, and 3 to 3·5 kg. of butter.

Of fresh Mysost, on an average, in addition to butter and skim-milk cheese, 6 to 7 kg.

Of fresh-pressed Ziger, in addition to butter and skim-milk cheeses, 2 to 3 kg.

Of whey in the manufacture of fatty cheeses, 73 to 88 kg., on an average 81 kg. In the preparation of half-fatty cheeses, 72 to 80 kg., on an average 76 kg.; and in the preparation of skim-milk cheeses, 66 to 76 kg., on an average 71 kg. In the manufacture of soft cheeses, under otherwise similar

conditions, for every 100 kg. of milk made into cheese, there are 5 to 7 kg. less of whey than in the case of hard cheeses.

The loss in cheese-making per 100 kg. of milk is, on a wide average, about 3 kg., not including the loss which arises in the ripening process.

128. The Chemical Composition and Analysis of Cheeses.—Cheeses, both such as are destined to be consumed fresh, as well as those which are allowed to ripen before consumption, are highly valuable, and to a large extent also, favourite articles of food. In the first place, they are rich in nitrogenous bodies. According to the method of preparation and the age, they contain between 18 and 50 per cent, on an average from 25 to 30 per cent, of nitrogenous matter. In addition, from 2·5 to 46 per cent of fat, and a not inconsiderable amount of mineral constituents, containing much phosphate of lime, are found in them. The kilogram of nitrogenous substance in cheese, more especially in skim-milk cheese, may be said to be cheaper than in almost any other article of food. Skim-milk cheeses are, however, as a rule, less pleasant in flavour and less digestible than fat cheeses. Emmenthaler cheese, which is easily digested, and of a fine mild flavour, satisfies all demands as a good suitable food. It is on this account eaten with bread alone, or with bread-and-butter, in larger quantities at one time than is the case with other cheeses. A not inconsiderable number of the different kinds of cheeses are used more as a bye-meat or appetizer than as an article of food for satisfying hunger, or as the chief constituent of a meal.

The chemical investigation of ripe cheese is a very difficult operation, which can only be imperfectly carried out, owing to the decomposition products which arise from the albuminoids and the fat during ripening, too little being known to permit of their being easily distinguished and their percentage exactly determined. All the complete analyses of ripe cheese at present available, with the exception of a few of the more recent researches, give merely a superficial and very unsatisfactory idea of the composition of cheese. In these analyses, what is designated as fat is the entire amount of body which has been extracted by ether or other fat solvent, regardless of whether it consists wholly of fat or not. The percentage of protein, or caseous matter, is generally expressed by a number obtained by multiplying the percentage of nitrogen found with a constant factor, viz. 6·25, which in the case of caseous matter is probably not once right. A determination of this kind is of little value, even

although it be correctly carried out, because ripe cheeses contain, in addition to unaltered nitrogenous matter, quite a number of products of the decomposition of nitrogenous bodies, which do not belong to the group of albuminoids.

The investigation of fresh cheese is much simpler, since, in its case, the individual constituents of the milk, although they have partly undergone change, are yet in a condition which does not offer especial difficulty in their separation and determination.

In the investigation of fresh cheese the following method may be pursued:—

(1) *Determination of Water and Fat.*—The sample of cheese to be investigated is cut into small square pieces, of which 2·5 to 5 grams exactly are weighed out, and carefully warmed to 40° C. They are then brought, in an open glass capsule, under the receiver of a hand air-pump, the air from which is pumped out. It is left for some time standing, again warmed, and this is again repeated, until no further loss in weight is observed. It is then digested several times with cold ether, removed from the capsule, and pressed in a dish. It is then brought on to a weighed filter; the capsule and the dish being rinsed with ether. The cheese is then extracted on the filter with warm ether, the different washings being all brought together. The cheese, from which the fat has thus been extracted, is dried at from 100° to 110° C., cooled, and is weighed on the filter, the weight of which is deducted. After the ether has been distilled off from the ether extract, the fat remaining behind is dried carefully at from 100° to 105° C., cooled, weighed, and the percentage of fat of the cheese thus estimated. By subtracting the sum of the weight of the cheese from which the fat has been extracted, and which has been dried, and of the fat, from the weight of the cheese originally taken, the percentage of water in the cheese is obtained. If the largest part of the water has not been removed before its treatment with ether, it may happen that in the extraction process small quantities of mineral salts, which are soluble in water, and perhaps also small quantities of milk-sugar, may go into the extract, and render the determination inexact. In the investigation of sour-milk cheeses, it must be remembered that the lactic acid present is soluble in ether. On this account the determination of fat must be carried out in a specially prepared sample, which has been rendered weakly alkaline with soda, and then carefully dried.

(2) *Determination of Nitrogenous Matter.*—This is determined in another quantity of the cheese, or in that portion from which the fat and the water have been separated, either volumetrically, by Dumas' method, or by the Kjeldahl process, the nitrogen obtained being multiplied by the

factor 6·39, on the assumption that the albuminoid matter of the milk contains 15·65 per cent of nitrogen.

(3) *Determination of Ash.*—This may be carried out in a special sample of the cheese, or on the portion which has been used for the determination of water, observing the precautions which are necessary in this process. The ash is determined by burning a small portion.

(4) *The Determination of Milk-sugar.*—The percentage of milk-sugar may be determined in perfectly fresh cheese by difference, if all the remaining determinations have been carried out in duplicate with great care. If it be desired to determine the milk-sugar directly, this may be done in a water extract, obtained by taking a portion of the cheese dried under the air-pump, rubbing it up thoroughly with pure sea-sand, and boiling it repeatedly with pure water. In order to separate the albumin from this water extract before treating it with the copper solution, it is necessary to acidify it with acetic acid, boil, and then filter.

In a perfectly exact analysis of fresh cheese, it must be assumed that the fat of the milk contains lecithin, and that, therefore, small quantities of nitrogen will be found in the fat of the cheese.

In the investigation of ripe cheeses there is no method which can be recommended as suitable or trustworthy. Manetti and Musso recommend the following:—Determination of the percentage of water and bodies volatile at 115° C.; preparation of a carbon bisulphide extract; preparation of an alcoholic extract; preparation of a watery extract; determination of the quantity of bodies insoluble in bisulphide of carbon, alcohol, and water; determination of the ash; determination of ammonia; determination of the sum of the acids present; determination of the nitrogen; and finally, the determination of the nitrogen and ash in the different extracts, as well as the determination of the nitrogen and ash in the residues of the different extracts.

As an example of the chemical composition of certain kinds of fresh cheese, and of products resembling cheese, the following figures may be given:—

	Neufchatel (Double Fat Soft Cheese).	Limburg (Fat Soft Cheese).	Emmenthaler (Fat Hard Cheese).	Backstein (Skim-milk Soft Cheese).	Raden (Skim-milk Hard Cheese).	Olmützer (Sour-milk Cheese).
Water, ...	34·5	35·7	36·1	73·1	57·3	44·6
Fat, ...	41·9	34·2	29·5	2·8	3·5	3·4
Nitrogenous matter, ...	13·0	24·2	28·0	19·8	33·0	41·1
Non-nitrogenous matter,	7·0	3·0	3·3	2·2	2·9	
Ash, ...	3·6	2·9	3·1	2·1	3·3	10·9
	100·0	100·0	100·0	100·0	100·0	100·0

	Ziger.	Mysost.
Water, ...	68·5	23·6
Fat.	3·1	16·3
Nitrogenous matter, ..	22·1	8·9
Milk-sugar, ...	3·2	37·3
Lactic acid, ...	0·8	1·1
Remaining constituents, ...	...	8·1
Ash, ...	2·3	4·7
	100·0	100·0

A study of the history of the manufacture of cheese, as carried out in different countries, shows that in three countries, viz., in Switzerland, in Holland, and in England, special kinds of preparation methods for the manufacture of hard cheeses have been in use from a very early period.

In South German hill districts, in Austro-Hungary, and over Italy, the Swiss method has been followed; in Schleswig-Holstein, in the Rhine Province, and over the whole of North Germany, the Dutch method has been adopted; and in the United States of America the English method has been preferred. France produces the finest and the most popular of soft table cheeses, Switzerland the best of hard cheeses, and Upper Italy the highly-prized Reib cheese. In Switzerland the manufacture of cheese is much more extensive than the manufacture of butter; the contrary is the case throughout Scandinavia, that is, in Denmark, Sweden, and Norway, as well as in Finland, in the Russian East Sea Provinces, in the whole of North Germany, and in a large part of France. The manufacture of butter, as well as of cheese, is carried on in North America, Great Britain, Holland, a part of France, South Germany, and over Italy. In Austro-Hungary, the manufacture of cheese, indeed the whole business of dairying, has up till the present time not received the amount of attention which has been devoted to it in most other countries.

CHAPTER VI.

PREPARATION OF KEEPING MILK, FERMENTED MILK, AND THE BYE-PRODUCTS OF MILK.

129. **Keeping Milk.**—By keeping milk, is understood milk which by heating, or by heating and other suitable treatment, possesses the property of being able to keep, without becoming decomposed, for a longer time than ordinary milk. As long as milk stands boiling without coagulation, and possesses no other foreign flavour than a slight taste of cooked milk, it may be regarded as a good keeping milk. The keeping qualities of milk, on the other hand, may be increased to such an extent, that it will keep for days, or months, or for a much longer period. In such cases the milk may possess its original percentage of water, or it may lose a portion of it by becoming thick.

130. **Pasteurized Milk.**—By such milk is meant that which has been heated, for a shorter or longer period, to a temperature under the boiling point of water, but high enough, as experience has shown, to kill most of the microscopic fungi. The temperature which meets these conditions, and which is consequently commonly used in Pasteurizing, lies between 56° and 80° C. Within these limits, the higher the temperature, the shorter is the period in which a distinct effect is produced. It would be very extraordinary, indeed, if milk were rendered free from spores by Pasteurizing. Since Pasteurized milk is scarcely ever kept free from spores, it possesses only, as a rule, a slightly increased keeping property. This is explained by the fact that the lasting spores of certain kinds of bacteria, which are not uncommonly present in milk, can withstand for a long time the application of such heat as is applied in Pasteurizing, and that there are bacteria which only begin to develop at temperatures over 50° C.; indeed, there are some which even rapidly increase at temperatures of from 70° C. to 75° C. Fortunately such bacteria as agree with these high temperatures are generally uncommon, and are only very rarely found in milk. Experiments have shown that in Pasteurizing, the vegetative forms of nearly all bacteria, and especially, also, of the most dangerous pathogenic germs,

such as cholera, typhoid, and tubercle bacilli, are killed. This, and this alone, is what is effected by Pasteurizing, and should always be effected by it. On this account, milk which has been so strongly and so long heated that the above results have been safely obtained, or milk in which the lasting forms, and the forms of such bacteria as prefer unusually high temperatures can alone be present, is named correctly Pasteurized milk. Correctly speaking, Pasteurized milk is, for example, milk which has been heated for 15 minutes at 75° C. or for 30 minutes at 68° C. The action effected by Pasteurizing is the more perfectly brought about the more carefully the operation is carried out. If it be desired to take every possible precaution, attention must be paid to having the milk contaminated as little as possible in the process of milking. The Pasteurizing apparatus should be cleaned for fifteen minutes before use, and the cooling of the Pasteurized milk should be carried out as quickly as possible in a cooler, which should also have been previously steamed. The cooled milk should then be put in steamed vessels, and care taken that it should not be left to stand for any time in uncovered receptacles. Properly Pasteurized milk keeps at ordinary animal heat for 20 to 24 hours at 20° C.; about 60 hours at 12° to 15° C.; 72 hours, and often even longer at lower temperatures, in a condition which admits of its being boiled without coagulation. It only possesses a flavour slightly suggestive of boiled milk, and may be converted into cheese, since its susceptibility to rennet has only been weakened to a very slight extent. In spontaneous coagulation it forms a comparatively spongy coagulum. Occasionally it is not lactic bacteria which induce, after a lapse of time, coagula-

Fig. 78.—Laval Milk Scalder.

tion of Pasteurized milk, but rennet and butyric acid bacteria. In such cases the coagulated milk exhibits only a slightly weak acid reaction, and shows near the surface a thin whey-like layer. If the creaming be effected, as is now beginning to be customary, by centrifugal force at 75° C., and the milk be kept fifteen minutes at this temperature, the cream is obtained, as well as the skim-milk, in the same condition as ordinary Pasteurized milk. If the creaming operation be followed at the temperature which is now customary, of 25° to 35° C., the skim-milk is often Pasteurized (fig. 78) in order to impart the necessary keeping qualities to it, and to permit of its regular transport to other places. Cream for butter-making should only be slightly Pasteurized if it be intended to be kept for a few hours only, or if it be intended to be soured with a pure culture of lactic ferment for the purpose of being made into butter.

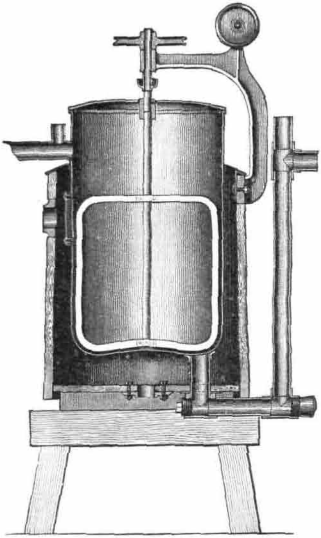


Fig. 79.—Pasteurizing Apparatus (Burmeister & Wain).

At the present time twelve different Pasteurizing apparatus for milk are known. The whole of the apparatus (figs. 79 and 80) have this in common, that the milk is stirred by metal paddles, which are heated by steam or boiling water. They are brought up as quickly as possible to the tempera*ture of 65° to 80° C., and have an uninterrupted flow of milk passing* through them.[8] They may be divided into classes, viz. those in which the milk flows out over a ribbed hot-plate, and those in which the heated milk flows through differently constructed closed spaces. All apparatus, without exception, suffer from two defects. The first consists in the

fact that in consequence of the strong and rapid heating of the nitrogenous matter, the milk forms a firm crust on the hot surface. This has to be prevented by special arrangements of the best possible kind. The second disadvantage consists in the fact that the apparatus works continuously, and that the only thing taken into account is to bring the milk

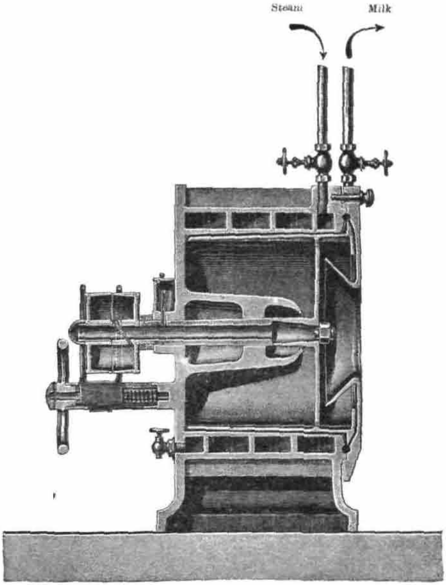


Fig. 80.—Pasteurizing Apparatus (Lefeldt).

quickly to a certain high temperature, and as soon as this temperature is reached, to allow it to flow away. In order to increase the capacity of the machine per hour, what is aimed at is to shorten as much as possible the period of the action of the temperature on the milk, and to raise the final temperature as high as possible. Since no apparatus among those above described may be said to yield with certainty properly Pasteurized milk, not one of them can be described as effecting what they ought to

effect. This is, however, no discredit to the makers, who do not know, and could not know, in constructing their apparatus, the cause of the defect. If it be desired in working with the apparatus in use to make sure that all the most dangerous pathogenic bacteria, and the vegetative forms of nearly all the remaining kinds of bacteria, have been destroyed, care must be taken, in the first place, that the milk be subjected in the apparatus to 75° C., and further, that the hot milk should be kept in special vessels for 30 minutes at a temperature of over 70° C. There is no Pasteurizing apparatus, therefore, as yet, which gives in a convenient, simple, and certain manner properly sterilized milk. Whether it is possible to manufacture such an apparatus, without doing away with the continuous flow of milk, must be decided by practical makers. Possibly, as H. Bitters has pointed out, the Pasteurizing apparatus of the future will be constructed in such a manner that the milk will not be heated in a continuous flow, but that it will be heated intermittently, and for a definite and high temperature, for a certain time.

131. **Sterilized Unthickened Milk.**—The perfect sterilization of milk, that is, the destruction of all spores in it, is extremely difficult. It can be effected, if desired, in a twofold manner. In the first place, it may be effected by heating the milk in strong closed vessels for several hours at a temperature of 110° C., or for 30 minutes at a temperature of 130° C.; or, secondly, by heating the milk on eight consecutive days, for two hours each day, at a temperature of 65° C., and keeping the milk in the interim period at a temperature of 40° C., that is, by intermittent sterilization, a method first employed by Tyndall. In the first method of treatment the value of the milk is lessened, since the particular qualities which are specially prized in fresh milk are entirely lost. The second method of treatment is so inconvenient, and consumes so much time, that although by this method the value of the milk is little affected, it cannot be carried out on a large scale. The perfect sterilization of milk by either method is of little practical importance, and can only be carried out in the laboratory for experimental purposes. In practice, one must be content with the empirical method of sterilization, in order to change the milk as little as possible, and be satisfied with destroying the vegetative kinds of bacteria, along with such pathogenic bacteria as may be present, and with acting upon the lasting spores, which may not be destroyed, in such a way that their capacity for development may be weakened, and that they may at ordinary animal heat only exercise a dangerous action

after being five to eight days in the milk, or, at ordinary temperatures, only after a lapse of weeks or months.

Sterilized milk, as almost universally prepared at present, is only sold in glass bottles, provided with hooped iron stopcocks and with a lead seal, and holding from ·250 to ·33 kilos. of milk. It has a flavour of boiled milk; the colour is either almost unchanged

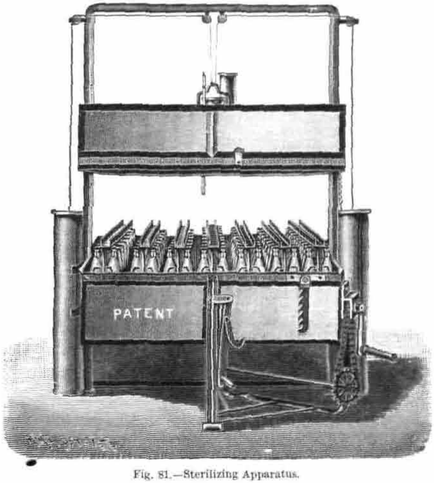


Fig. 81.—Sterilizing Apparatus.

or is of a distinct bright yellow. It contains no soluble lime salts and no soluble albumin. It is unsusceptible to the action of rennet, and yields, when coagulated with acids, a fine flocculent coagulum. The author, in collaboration with Dr. Aug. Morgen, showed, in 1883, that the nitrogenous matter in milk, which has been submitted to high temperatures, is somewhat more digestible than in fresh milk, a fact which has subsequently been confirmed by Raudnitz and Stutzer.

Nearly all sterilized non-thickened milk is used for children, and is used without delay. Although it is easy enough to keep it for weeks, it is not well suited for this, since it is very quickly sepa-

ated by the action of gravity into cream and skim-milk, which do not subsequently admit of perfect admixture. On this account, unlike wine, beer, and other beverages, it cannot be kept in the cellar for a long time, nor is it suited for use on board ships, nor for transmarine export. This method of preserving milk is open to the objection that seven-eighths of the weight of the milk consists of water, and on this account it can scarcely be described as possessing a valuable economic property, which distinguishes articles used for transport. It is not, therefore, suited for keeping for a long time, or for export on a large scale. Condensed milk is better adapted for this purpose.

A well-known apparatus for sterilizing large quantities of milk, in the method above described, is the sterilizing apparatus of Neuhausz, Gronwald, and Oehlmann (fig. 81), which is manufactured of four different sizes for treating 50, 104, 150, and 238 bottles respectively

132. Condensed Milk.—The experiments and attempts which have been made to convert milk by various methods into a condition in which its most valuable and most essential properties may remain unchanged for a long time, if possible for years, date back to the early part of the present century. Although the many and various attempts which were made, up to the middle of this century, were all failures, they cannot be regarded as valueless, since they paved the way to the method in which the object aimed at can alone be effected. In the first place, they have shown that milk, in *order that its usefulness for transport should be increased, and that at the same time its keeping power be strengthened, must be deprived* of a portion of its water; and in the second place, that steaming the milk in vacuum, at a temperature under 70° C., is necessary, and that these are indispensable conditions to the utility and value of the process. In the earliest attempts made in the United States of America to change milk into an article which might admit of being kept, the experiment was made of withdrawing all the water from the milk, and of pressing the dry substance, to which small quantities of bicarbonate of soda had been added, into cakes. Messrs. Dalson, Blatchford, and Harris set up a manufactory about the year 1850, in the neighbourhood of New York, in which cakes of milk were made according to the directions of E. N. Horsford. It was believed that everything had been discovered and the desired object attained. It was soon found, however, that the new preparation did not come up to expectation. The milk cakes kept badly, as the fat

in them developed a slightly rancid flavour; while they did not completely dissolve. On mixing them with water, a liquid was obtained which no doubt possessed the appearance of milk, but was in reality nothing else than a mixture of milk powder in water, since the nitrogenous matter of the milk which had been dried did not dissolve or swell out; that is to say, did not assume the condition in which it was originally present in the milk. This result raised the question of whether it was possible to obtain a substance under the name of milk, by fully drying the milk and by again dissolving it, and finally decided it.

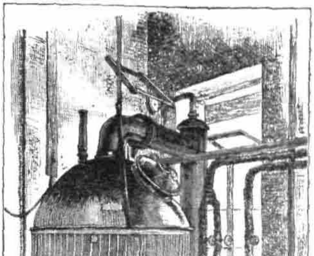


Fig. 82.—Vacuum Pan for Condensing Milk.

On the 19th of August, 1856, Gail Borden took out a patent in America for the preparation of condensed milk by use of a vacuum pan (fig. 82), without the addition of sugar, or of any other foreign substance. The viscous condensed milk, prepared by him on a commercial scale, and packed in open cans, excellently fulfilled all the requirements if not kept too long, but suffered from the drawback that it could be kept unchanged only for a few weeks. Gail Borden then tried condensed milk with the addition of sugar, packed in air-tight soldered cylindrical metal tins. This method at length solved the problem in a satisfactory manner. As the method of preparing condensed milk at present in practice is essentially the same as that introduced by Gail Borden, his name is with justice regarded as the discoverer of a method of condensing milk.

In the year 1865, C. A. Page, at that time consul in Zurich,

erected a factory in Switzerland for the preparation of condensed milk, prepared with sugar. He was succeeded by the Anglo-Swiss Condensed Milk Co., which founded in 1866 at Cham, on the Lake of Zug in the Canton of Zug, a large factory, which was the first factory for the manufacture of condensed milk started in Europe. The company still exists, and in addition to its chief factory at Cham, has branches in England, in Switzerland, and South Germany, and practically supplies the entire European market with condensed milk. In the course of time many other similar factories have been erected in different districts, nearly all of which, however, have come to grief. The experience which has been acquired up till the present time in the preparation of condensed milk, points to the fact that the fresh milk should be previously warmed, with 12 to 13 per cent of its weight of cane sugar—beet sugar has proved itself unsuitable, —and then condensed in a vacuum pan to about one-third or one-fourth of its volume.

Thickened milk possesses a white or whitish-yellow colour, according to its age, and is of a very sweet pleasant flavour. It has a thick pulpy consistency, and has the power of keeping for a long time.

If condensed milk be mixed with four and a half times its weight of pure lukewarm water, it is perfectly dissolved, and forms a milky, sweet, and pleasant liquid, which possesses the flavour of ordinary fresh milk. If allowed to stand for some time, a layer of cream is thrown up, which may be made into butter.

According to all the available data collected by the author, condensed or preserved milk, prepared by the addition of cane-sugar, has the following composition:—

	Average.	Limits of Variation.
Water, ...	25·680	12·43 to 35·66 per cent.
Fat, ...	10·985	7·54 „ 18·78 „
Nitrogenous matter, ...	12·325	7·79 „ 20·14 „
Milk- and cane-sugar, ...	48·662	41·25 „ 53·89 „
Mineral matter, ...	2·342	1·56 „ 3·87 „
	100·000	

The relation between milk-sugar and cane-sugar is as follows:—

	Average.	Limits of Variation.
Milk-sugar, ...	16·288 per cent.	10·82 to 18·35 per cent.
Cane-sugar, ...	32·374 „	24·11 „ 40·48 „

The specific gravity of preserved milk, containing cane-sugar, at 15° C., varies between 1·2540 and 1·4038, being on an average 1·2820. Preserved milk, without the addition of sugar, which is much used in the United States of America, has not been prepared in Europe since 1880. The chemical composition of American thickened milk, without the addition of sugar, is as follows:—

	Average.	Limits of Variation.
Water, ...	48·595	46·40 to 53·54 per cent.
Fat, ...	15·668	13·12 „ 19·80 „
Nitrogenous matter, ...	17·806	13·61 „ 26·50 „
Milk-sugar, ...	15·403	12·50 „ 17·75 „
Mineral matter, ...	2·528	2·00 „ 2·96 „
	100·000	

The specific gravity of American thickened milk is, on an average, at 15° C., 1·136. Attempts to condense skim-milk, mares' milk, and goats' milk, have also been made.

Shortly after the method introduced by Scherff for the sterilization of milk had become known, the idea was carried into effect of rendering the condensed milk capable of being kept by sterilizing it, and thus dispensing with the addition of sugar, which, by imparting to it a very pronounced sweet taste, rendered it disagreeable to many people. For this purpose experiments were carried out during the years 1881 to 1883 in different parts of Germany and Switzerland. Sterilized condensed milk was best obtained by purifying the fresh milk by the application of centrifugal force, and then boiling it in order to coagulate the albuminous part of the nitrogenous matter. This was condensed in vacuum-pans to a third or fourth of its original volume, and poured into metal vessels of the same shape and size as are used in the factory at Cham. The vessels, after being filled and soldered, are placed for a short time at a temperature of about 120° C., the keeping quality of the substance being tested by submitting it for a few weeks to a temperature of from 30° to 40° C., and after the lapse of this time seeing whether there have not been indications of fermentation shown by distention at the bottom or at the top of the vessels. If it be neglected to heat up the milk before it is condensed, the albumin is coagulated during sterilization, and renders the contents of the can lumpy.

If the preparation of condensed milk without the addition of cane sugar is carried on with the necessary precautions, the product obtained is a body possessing great keeping properties, which, when dissolved in a suitable quantity of pure water, yields a liquid possessing all the properties prized in fresh milk, and which indeed leaves little to be desired. Good milk of this sort is manufactured by the manufactory of Drenckhan, in Stendorf, near Eutin, and others. The chemical analyses of several samples of such milk yield the following average compositions:—

	Samples from Stendorf.	Bremen.
Water, ...	66·2	63·8
Fat, ...	8·4	9·8
Nitrogenous matter, ...	10·9	10·4
Milk-sugar, ...	12·3	13·7
Ash, ...	2·2	2·3
	100·0	100·0

The specific gravity of condensed milk of the above composition at 15° C. is about 1·1.

133. **Fermented Milk.**—By inducing alcoholic fermentation in milk by suitable means, it is possible to prepare from it spirituous beverages. Two beverages of this kind are known, viz. kephir and koumiss, which are prepared by the aid of different kinds of ferments. In the preparation of these two beverages, it is found that during the alcoholic fermentation, going on at the expense of the milk-sugar, a decomposition of the milk takes place, accompanied with the formation of lactic acid, and the casein separates out in a solid form. Since this decomposition does not exceed certain well-defined limits, and the quantities of lactic acid and alcohol do not exceed a certain amount, the beverages cannot be kept at the ordinary temperatures for any length of time without a certain loss of their beneficial properties; but must be consumed when they are only a few days old. Kephir and koumiss possess a frothy appearance, and a taste resembling butter-milk, and contain the casein in the form of a fine suspended coagulum. They are as nutritious as they are easily digested, and exercise, when regularly taken for some time, an excellent dietetic action, which may be ascribed chiefly to the percentage of milk-sugar, alcohol, and carbonic acid they contain. Good kephir should not contain more than 1 per cent of alcohol and lactic acid, and good koumiss not more than at the most 2 per cent of alcohol and 1 per cent of lactic acid.

Under fermented milk may be mentioned the "ropy" milk which is still prepared in Scandinavia. The fermentation which takes place in this kind of milk has, however, nothing to do with alcoholic fermentation.

134. **Kephir**, or **Kefir**, **Kyphir**, and **Kafir**, and, as it is known in the Caucasus, **Kyppe**, was for long only known to the hill-dwellers in the Caucasus. In Germany it first became known in the year 1882. It is prepared from the milk of different mammals, chiefly from cows' milk, with the help of a special ferment. This ferment, the so-called kephir grains, which are granular lumps about the size of peas or beans, of a hard nature, and of a yellow colour, is first dissolved in water, to which milk is added. After a few hours, at a suitable temperature, fermentation takes place, accompanied by an active evolution of gas, which is accompanied with a slight characteristic noise. After two or three days the kephir is ready for use. By frequently shaking the vessel in which the kephir is contained, first the separation of cream, and subsequently the formation of a lumpy coagulum, are retarded. The kephir grains, which are known in the original habitat of the kephir as the "Prophet's grains", on account of their value, consist of yeast cells and bacteria, the nature and action of which has been investigated by Hueppe. The results of his investigations have been discussed in § 44. They convert a portion of the milk-sugar into lactic acid, and another portion into alcohol and carbonic acid, but they do not appear to alter the nitrogenous matter of the milk, at any rate not to any extent. Kephir is best prepared at 12° to 15° C., since the fermentations at this temperature proceed quietly, and the lactic fermentation especially is delayed to a desirable extent. The casein separates out at the beginning of the fermentation in a finely flocculent condition, which, as long as the evolution of carbonic acid actively continues, collects in the upper portion of the bottle, above comparatively clear whey, and which later on sinks to the bottom, and may thus be perfectly distributed throughout the liquid by shaking.

Good kephir should foam, and should neither taste strongly acid nor possess a lumpy coagulum. It is used as a tonic for convalescents and weak people, and is specially adapted for those patients in whom it is desired to raise the general strength of the system. Its action in all cases is excellent.

In the preparation of kephir, the first point of importance is to bring the kephir grains to a state of great activity. For this purpose they are soaked in water at 30° C., allowed to stand for several hours, and then they are drained off. The swollen grains are then washed with pure water. They are put in ten times the quantity of boiled milk, and cooled to 20° C. They are left standing at 20° C., repeatedly shaken, and after the lapse of an hour the milk is poured off. This is repeated for six or seven days, or even for a longer period—so long, indeed, as the liquid possesses the smell of sour milk, and till the grains are perfectly swelled and begin to rise to the surface.

The grains thus prepared are again put in ten times their weight of milk, which has been boiled, and then cooled to 20° C. They are allowed to stand half a day at 20° C., are filtered through gauze, and placed in new milk in the same manner. The filtrate which is poured off, and which is not usually pleasant, is poured into half-sized champagne bottles to the extent of 75 c.c., which are then filled with boiled milk, cooled to 20° C., and corked. The bottles are allowed to stand at 15° C., and during the first day are hourly shaken, and after two to three days are used. The swollen kephir grains which are used must be freshened up every eight days. In order to do this they are washed with pure water, soaked in a 1-per-cent soda solution, and left to steep in it for about two hours. They are then vigorously stirred, and washed again with water.

Among the few scientific investigations which have been carried on up till now with regard to kephir and its preparation, the bacteriological investigations of Hueppe and the chemical investigations of Hammersten are the most striking. According to Hueppe, the kephir grains not only cause a lactic and alcoholic fermentation, but also peptonize a portion of the casein and albumin in milk. Hammersten, on the other hand, has shown that in kephir, bodies of the nature of peptone are only present in small and diminishing quantities, and that true peptone—that is, albuminoid bodies which are precipitated by saturating the solution with sulphate of ammonia—do not occur. He has further shown that kephir casein is not practically different from milk casein. It is true that it is less soluble in the carbonates of the alkalies, and dilute salt solution and dilute hydrochloric acid, than milk casein. Since, however, casein, separated by the spontaneous coagulation of milk, is of a similar nature, it cannot be said that in the preparation of kephir from milk there is any real change in the condition of the casein. Three samples of kephir from Gothenburg, which Hammersten has submitted to accurate investigation—about the age of which nothing is stated, but which appeared to be about four, or at the most, six days old,—had the following average composition:—

Water, ...	88·915
Fat, ...	3·088
Casein, ...	2·904
Lactalbumin, ...	·186
Peptone, ...	·067
Sugar, ...	2·685
Mineral matter, ...	·708
Alcohol, ...	·720
Lactic acid, ...	·727
	100·000

With regard to the specific gravity of kephir, we have no data. Probably it is a little lower than that of milk, but not much different.

Struve found in kephir grains which he had examined 11·21 per cent of water, 3·99 per cent of fat, 51·69 per cent of albuminoids, of which 10·98 per cent were soluble in water, 10·32 per cent soluble in ammonia, and 30·39 per cent soluble in dilute soda solution, and 33·11 per cent in an insoluble condition.

If it be desired to keep kephir longer than three or four days, it must be laid in ice. G. Marpmann recommends that the kephir be sterilized as soon as it has acquired the desired condition, in order that the process of fermentation may be stopped.

The kephir ferment may be kept for half a year or longer, without losing its vitality, if it be thoroughly dried in the sun in a cool dry place. At present kephir can be easily obtained in every large town in Germany.

135. **Koumiss.**—Koumiss, or, as it has been called, milk-wine, (*vinum lactis*, or *lac fermentatum*), is milk which has undergone alcoholic fermentation. In taste and smell it resembles butter-milk, or slightly sour whey, and presents a foamy appearance. It contains its casein in the form of a very fine floating curd. Koumiss was originally prepared in the steppes of the south of Russia and Asia, where it has been used for hundreds of years by the different nomadic tribes inhabiting these districts. It is chiefly prepared from mares' milk, but may also be prepared from skimmed cows' milk. The best koumiss prepared from mares' milk is said to be that manufactured in the Russian province of Orenburg. Good koumiss is in every respect very similar to kephir, although inferior to it, and is used very much in the same way. In Russia, mares'-milk koumiss has been long used for sleeplessness, and it was formerly the custom in summer to send invalids undergoing the koumiss cure

to a Cossack village in the steppes. At present there are, in different districts of Russia, at Samara, Odessa, and at Ufa in the Urals, and elsewhere, well-equipped establishments, conducted under the direction of physicians, where the koumiss is prepared. With regard to the nature of the koumiss ferment, no extensive investigations have as yet been carried out, nor has the chemical composition of koumiss been so exactly determined as that of kephir.

As already stated, the word koumiss is derived from the name of an old tribe, the Kumanen, mentioned by Xenophon and Pliny, who first prepared koumiss, and who in the course of time transmitted the knowledge to other tribes. There is historical evidence to show that koumiss was already known to the Tartars as early as the thirteenth century.

Koumiss has been prepared by different methods in the past. One method was by putting old koumiss, or the residue obtained by drying koumiss in the sun, into a vessel, pouring fresh mares' milk in, and stirring for fifteen minutes, the mixture being left to stand all night. Next day fresh milk was again added, and the mixture again stirred, this being repeated as often as possible in the course of the day. By this method a weak preparation of koumiss is obtained in the evening, which may be transferred, with the exception of a small residue, to another vessel. In order to prepare more koumiss, fresh milk is added to this residue, and the same process carried out. In this way, on the evening of the third day, a preparation of weak koumiss, as well as a preparation of fairly strong koumiss, is obtained. This process may be repeated as often as desired.

An approved method of preparing koumiss from skimmed cows' milk is as follows:—100 kilos. of skim-milk, obtained from the separator, and mixed with 42 kilos. of water, 1·75 kilos. of ordinary sugar, ·78 kilos. of milk-sugar, and 160–180 grams of yeast, is allowed to stand for 32 hours at 37° C. During this period the mixture is stirred about six times at equal intervals. It is then carefully decanted into champagne bottles, corked and fixed with wire, and the bottles left in a cellar at a temperature of 12° C. It is not desirable to keep it, at the very most, more than six days at this temperature, since it gets too sour.

Good koumiss, six days old, has a specific gravity of 1·008 to 1·020, and the following composition:—

	Mares' Milk Koumiss.	Skimmed Cows' Milk Koumiss.
Water, ...	91·535	88·933
Fat, ...	1·274	·854
Albuminoids, ...	1·913	2·025
	94·772	91·812

136. Ropy Milk.—The so-called "ropy" milk is milk which has been converted by the fermentation of certain kinds of bacteria into a peculiar condition. It is of a thickish uniform leathery consistency, and runs, when poured from a spoon, in threads of considerable length, which often draw out to the fineness of hairs. It tastes slightly sour, contains its casein in the form of an extremely fine suspended flocculent powder, and, at a comparatively low temperature, may be kept for months in an almost unchanged condition. It is much liked in Norway and in Northern Sweden and Finland, where it forms an article of commerce. The author has seen such ropy milk at the market at Helsingfors, whither it had been brought in little wooden barrels by the peasants living in the neighbouring districts. The method in which *lange milch* is prepared in the above-mentioned countries we do not exactly know. It is also unknown whether its condition is due to zooglœa-building bacteria, or bacteria which convert the milk-serum into a thready condition through change of the milk-sugar. The author is not aware of any accurate analyses that have as yet been made of ropy milk.

Lange milch is not used in Germany as an article of food. It is, however, occasionally known as an undesirable disorder in milk. As such disorders are not altogether uncommon, and, as the author knows by experience, often occur in well-conducted dairies, it follows that the bacteria which induce this thread-like consistency in milk or cream must be of pretty wide occurrence. It has been asserted that ropy milk may be prepared by the help of a plant, Pinguicula, in those countries in which it is regularly made. The author doubts this, however, since in repeated experiments with the *Pinguicula vulgaris* and the *Pinguicula alpina* he has never succeeded in producing this thready consistency in milk. If, however, it does take place, he believes it must be attributed to the agency of bacteria, which change the milk in this way, and which find in the above-mentioned plant a congenial nourishing soil, and hence are often found in it.

137. Milk-sugar.—Of all the bye-products of milk, milk-sugar is by far the most important. Milk-sugar, the properties of which have been more particularly described in § 7, can never, on account of its hardness and its only slightly sweetish taste, supplant cane- or beetroot-sugar for ordinary domestic purposes, but for almost all technical uses to which sugar is put, it is as suitable as the other two kinds of sugar. Its use, however, is handicapped by

ts high price, which is due to the fact that it is only found in the nilk of mammals. It may be described as of rare occurrence in nature; furthermore, it is only obtained from one mammal, namely, from the milk of the cow, while on the other hand the raw material for the manufacture of cane- and beetroot-sugar is very abundant. Milk-sugar differs from cane and beetroot, as has already been pointed out, chiefly by its much weaker sweetening power, and by the fact that it is much less soluble in water than the other forms of sugar, and forms saturated solutions which are not of the nature of syrups, but are of a limpid consistency. These properties render it very valuable for many purposes, especially for medicinal use. It is used in medicine in the preparation of homœopathic medicines, for the purpose of diluting saccharine or powerfully acting drugs, which have to be taken only in very small quantities, and also as an addition to milk to be employed for the feeding of children during the period of infancy. It has further been used for the purpose of adulterating wine, and in certain purely technical arts. On the whole, its use is comparatively limited, and can scarcely be expected to be much extended. In the ordinary method of the manufacture of milk into cheese, about 85 per cent of the entire amount of the milk-sugar in the milk passes into the whey, with the result that this latter contains on an average about 4·8 per cent of milk-sugar.

Whey is the raw material from which milk-sugar is prepared. Its condition, the lactic and acetic acids it contains, its albuminoids and mineral salts, and especially the alkali salts, increase the difficulty of separating the milk-sugar. By the action of the acids and the mineral salts, a portion of the milk-sugar is carried away in the process of crystallization, and is thus lost. By the addition of milk of lime the acids may be fixed, but the alkali salts cannot be removed, and what is gained on the one hand is lost on the other, by the formation of a compound of sugar and chalk. And since the albuminoids which are present impede the crystallization of the sugar, even under the most favourable conditions, it is not easy to obtain more than 66 per cent of the milk-sugar in the whey. In the preparation of beetroot-sugar, 80 per cent of that originally present in the raw material is easily obtained, while in the preparation of cane-sugar a still larger yield is obtained. Thus, owing to the fact that only a comparatively small portion of saleable sugar can be recovered from the milk-sugar in the whey, and that

the whey on an average contains only about 4·8 per cent of milk-sugar, while the sap of beet-root and sugar-cane contain more than three times as much, the conditions for the manufacture are not of such a nature as to be profitable; and, in addition to all this, the limited uses of milk-sugar have to be taken into account. The experience of the last twenty years has shown that the preparation of milk-sugar from whey is not remunerative. It can only become so if the business is carried out on a large scale.

In the preparation of milk-sugar on a large scale, the whey is evaporated down in vacuum pans, either to the condition of a thin syrup, and then the sugar is allowed to crystallize out, or it is evaporated down till the sugar crystals separate out by means of centrifugal force from the syrup. The residue is utilized for the feeding of swine, since it is not worth while to recover, by osmosis, the sugar still remaining in the syrup.

In order to refine the raw milk-sugar, it is first of all dissolved in water, the solution is then filtered, and to the filtrate there are added, for every kilogram of sugar, three grams of sulphate of alumina and five grams of milk of lime. The solution is then boiled for five minutes and filtered, and in order to remove the colour the filtrate is passed through carbon filters. The crystallization of the sugar from the solution is promoted by the addition of alcohol. The sugar is obtained in the form of crystallized sticks, which are obtained by suspending threads of cotton wool or thin sticks of wood in the solution of sugar, and allowing the crystals to deposit round them, and is known as grape-sugar, in distinction to the sugar which is obtained in the form of plates by allowing it to crystallize on the bottom and sides of the vessel, which is known as flat-sugar. The grape-sugar is purer than the flat-sugar. By repeated crystallizations milk-sugar may be obtained in transparent glassy crystals, which possess a retail value per kilogram of from 2·2 to 3·3 marks.

Before 1880 there was only one dairy factory in Germany in which milk-sugar was made, but since then Switzerland supplies all the milk-sugar used. It is prepared in the summer-time in the Canton of Berne, where neither the labour nor the fuel are especially expensive, by simply evaporating the whey in cheese-kettles over an open fire. It is obtained in the form of a gritty material, the so-called "sugar sand", which is of a light yellowish gray colour, and is comparatively impure. The evaporation of 500 kilograms of whey occupies about 24 hours. This sugar sand is bought by merchants and refined. In the year 1876 it was valued in the Alps at ·6 to ·7 marks per kilogram, while the value of grape-sugar and flat-sugar, according to purity, varied from 1·12 to 1·3 marks per kilogram.

Two samples of milk-sugar analysed by Dr. Gerber had the following compositions:—

	(1)	(2)
Water and volatile substances, ...	5·67	9·48
Milk-sugar, ...	92·49	86·28
Albuminoids, ...	*1·10*	*3·90*
Ash, ...	·74	·33
	100·00	99·99

Sample (1) came from East Russia, and sample (2) from Marba, in Canton Lucerne, Switzerland. Nothing is known with regard to attempts made to adulterate milk-sugar. The percentage of pure sugar, in the commercial sugar, is determined in the same way as in ordinary sugar.

138. Bye-products of Milk of Minor Importance.—Among the different foods prepared from milk, the following, only known in the East, may be mentioned:—

Keschk, small rods or balls, obtained by thickening very sour butter-milk, and used in Asia, from Syria to Afghanistan, or Turkistan, as an addition to herb porridge. The very dark-coloured residue remaining, after the making of *keschk*, possesses a sour and salt-like flavour, and is also used as an article of food, and is called *karagrut*. If milk be coagulated by the addition of *keschk*, a substance called *jaurt* is obtained, which, when mixed with salt and water, constitutes a favourite dish. We have already discussed in § 126 the preparation of effervescing beverages from whey, and the hitherto unsuccessful attempts to prepare alcohol or vinegar on a large scale from whey.

The application of liquid milk products and caseous matter in certain trades, depend, on the one hand, on the fact that solutions of casein, when dried, form a hard, horny, elastic mass, not readily soluble in water, and, on the other hand, on the fact that casein forms, with the oxides and salts of the metals of the calcium group, a cement-like compound, insoluble in water.

It has been known for centuries that the peeling off of whitewash may be prevented if butter-milk or whey be substituted for the milk of lime.

For painting wood which it is desired to protect from the influence of the weather, there should be used either a cement which has been stirred to a thick paste, or a mixture of curd, linseed oil,

chalk, and water. Emulsions of olive oil in milk are used in the manufacture of wool, for the purpose of adding fat to the wool.

Laciarine, or casein gum, is almost pure casein specially prepared, which, when dissolved in ammonia, is used for fixing and thickening colours in calico printing. Casein lime, or casein cement, is made out of skim-milk cheese very poor in fat. It is very useful, and is much used in carpentry. The cheese is cut into small morsels, quickly dried, and ground into a fine powder, which is mixed with 20 per cent of burnt chalk. If it be desired to keep it for some time, it must be put into closed vessels and mixed intimately with not more than 1 per cent of camphor. Casein lime comes in fair quantities from Switzerland.

Lactite, or milk ivory, is a hard horny substance prepared from casein. Attempts are at present being made to introduce it for technical purposes. The author has a black button made from this substance, which is externally indistinguishable from a common bone button. Whether this is a lucrative application of casein, and whether the new substance is able to replace horn or bone, remains to be seen.

CHAPTER VII.

THE ECONOMIC ASPECTS OF DAIRYING.

139. The Sale of Milk for Direct Consumpt.—Among the ordinary methods of utilizing milk which have been practised for any length of time, it may be said that the sale of milk for direct consumpt is the most lucrative. This method of distributing milk is widely practised wherever a dense population causes a large demand for fresh milk. The price of a litre of milk is, under these circumstances, always at least so high that it approximates to the average price obtained by manufacturing (churning) the milk in the country. It increases, of course, as the expenses in its distribution increase. It is only when the development of the conditions of trading does not keep pace with the growing demand, that the price of milk can exceed the above limit. According as the supply is lightened, facilitated, and rendered cheaper, so is the field extended for which the sale of fresh milk is the proper and economical method of milk distribution. The question then presents itself to farmers who have churned their milk, whether they should still adhere to this method; or whether they should give it up and sell the milk. The decision of this question is very easy for anyone who has a well-kept farm. He has simply to calculate the highest limit of value which, under the most favourable circumstances, he can obtain per kilogram of milk, calculated on the basis of its composition. This is furnished him by an examination of his accounts, as well as by a statement of the total expenses which he may incur in its distribution, and then he may compare these sums with the market value of a kilogram of milk. The disposal of milk by selling it in a fresh condition necessitates only a slight expense in utensils, and is accompanied by little risk. It also affects the management of a farm very little, so long as the consumer is quite indifferent to the quantity of fat and total solids contained in the milk, and it keeps the capital of the farm circulating quickly and regularly throughout the whole year. All that is necessary is to regulate the time of the calving of the cows to suit the trade, and to see that the necessary food is supplied at each season of the year, so that a uniform quantity of milk be provided throughout the whole year.

This method of utilizing milk is as well suited for the occupant of a small farm as of a large, with the exception that the latter has this advantage over the former, that he can distribute his larger amount of milk over wider areas at the same expense per gallon. This mode of milk disposal is not well suited where the rearing of calves is practised. It is also to be noted that where the milk is sold off the farm, all the mineral constituents of it are lost. An increased price can under certain circumstances be obtained for milk by sterilizing it, or by exercising that amount of care which is necessary to fit it for sale in milk-curing establishments or in the rearing of children. If this be done, however, a considerable increase of expense is incurred in plant.

140. **Utilization of Milk by making it into Butter.**—On dairy-farms, where the sale of fresh milk is, for economical reasons, impossible, the attempt is generally made to utilize milk by converting it into butter, to a far greater extent, than by converting it into cheese. The reason of this is chiefly, but not entirely, due to the fact that butter is the most largely required milk product. It is also to be considered, that the variation in the percentage of bacteria in the milk, due to the utilization of the most widely different kinds of food, does not affect the preparation of butter—a fact which in earlier times was rarely noticed, and which at present can be rendered absolutely of no effect by Pasteurizing the cream, so that the preparation of butter is, to a large extent, independent of certain changes which affect the preparation of fat cheese. Finally, it must not be overlooked that the preparation of butter demands more care and attention than peculiar skill. The above-mentioned facts cause the preparation of butter to be a very widely practised art.

The utilization of milk by manufacturing it into butter requires a larger expenditure in plant than the sale of milk; it does not obtain so quick or so regular a return of the capital employed. In dairy-farming, this method for the disposal of milk is not so popular, since it requires more attention to the feeding of milk cows, more time and knowledge for its supervision, more human labour, and lastly, special arrangements for disposing of the bye-products. By the sale of the butter practically no mineral constituents are removed from the soil of the farm. The keeping qualities and the large demand for butter offer many commercial advantages. For one thing, the product may be temporarily stopped if the times are

unfavourable. For another thing, more distant markets may be sought. Where butter is prepared, the rearing or fattening of calves or of swine is carried on, or, less frequently, the preparation of skim-milk, when all bye-products, both of the butter and the skim-milk, are utilized for feeding swine. It may be calculated that every four cows keep, on an average, one old and one young pig, and every four to five cows a breeding sow.

The manufacture of butter may be effected on a small scale as well as on a large scale, but is more lucrative on the latter scale. The prices of the butter market show that butter made in large dairies is, on an average, better than that prepared in small dairies. On small farms it is not convenient to churn every day.

141. **The Utilization of Milk by converting it into Fat Cheese.**— The fact that the practice of making fatty cheeses is less extensive than the making of butter, is due to the fact that the former method of utilizing milk is largely influenced, as has been pointed out, by certain local conditions, as well as by the fact that the art of cheese-making not merely requires aptitude and care, but involves reflection, skill, and experience. The assertion that the practice of cheese-making prevails in mountainous districts, and in districts thinly populated, because cheese keeps better than butter, is by no means correct. The conditions necessary for the successful manufacture of fat cheeses do not admit of such perfunctory dismissal. Fatty soft cheeses are almost always less easily kept and less in demand than salt butter. Only certain kinds of fat hard cheeses are unconditionally superior to butter in this respect.

It may be regarded as beyond doubt that the ripening of cheese is effected by bacteria. On the one hand, we know that the different kinds of bacteria exercise different kinds of actions, and, on the other hand, that certain kinds of cheeses are characterized by particular properties. From this it may be inferred that the ripening of each kind of cheese is dominated by a particular kind of bacteria. If this is correct, it follows, further, that each kind of cheese will be most successfully manufactured when the proportion of the kinds of bacteria implicated in the manufacture of the cheese are present in the right quantity. Since milk leaves the cow's udder free from bacteria, it follows that nearly all the bacteria which lodge in it are derived from dirt, which comes into it chiefly from cow dung. The bacterial percentage in dung depends directly on that in the food, and this is influenced indirectly by the manuring and by the different

kinds of food. In districts where manures of the most various kinds are applied, and in which not only the kind of feeding but also the condition of the fodder varies on different farms, and in the course of a year even on the same farm, to a considerable extent, the percentage of bacteria in the milk must be naturally subject to great variation. If this is the case, the ripening of cheese, when the method of treatment remains the same, cannot possibly be of a uniform nature. The success of the cheese manufactures will be more or less affected, if not entirely jeopardized. These conditions are most active in the case of the preparation of the best hard fatty cheeses, which ripen slowly. They have little effect, it would appear, on fat soft cheeses, the ripening of which begins on the surface and develops towards the centre, nor have they much effect on skim-milk cheeses. In certain districts of Switzerland on the one hand, and in Holland on the other, the conditions favourable for the manufacture of fine fatty hard cheeses are especially favourable. In both countries the cows feed through the entire summer on excellent pastures, during winter-time on good hay. In both countries the similarity of the feeding of the cattle, and the treatment of natural pastures, effects a uniformity in the bacteriological condition of the milk, which is scarcely found elsewhere in Europe. Nevertheless, these two countries are not exactly on the same level, Switzerland, with its high-lying Alpine pastures, coming before Holland. The deep and moist marshes are undoubtedly richer in bacteria than the Alpine ones. We have already seen that in Holland, in the preparation of the much-prized kinds of cheeses, the percentage of bacteria in the milk has to be influenced by the addition of ropy whey to the milk. Although Emmenthaler cheeses on the one hand, and Gouda on the other, are no longer, as was formerly the case, only made in summer, but also in winter, and although they are no longer exclusively manufactured in Switzerland and in Holland but also in other countries, it still remains the fact that summer cheese is superior to winter cheese, and cheeses made in those countries with which the manufacture of the cheese has been long associated are better and finer than those made in other countries.

Good butter finds a ready market everywhere, but the different kinds of fat cheeses are not equally liked in different localities. It is, therefore, of the highest importance in the manufacture of cheese to ascertain exactly what the taste for cheese is, and only to prepare

cheeses which are in demand, and which are thus sure of a market. It must also, however, be clearly understood that it is necessary to make cheeses of a good quality, and not to think that this is of easy accomplishment. For this purpose, in deciding the question of whether it is more advantageous to make butter or cheese of this or that kind of different fat cheeses, it is also necessary to consider, along with this general question, others connected with the economic side of the question, and especially the local and natural conditions influencing the exact bacteriological condition of the milk, which produce in different districts and countries the predominant flavour. It is also necessary to consider the absence or presence among the people of a cultivated taste for cheese.

If the trade in fatty cheeses requires less capital involved in plant than that in butter, it nevertheless requires a large circulating capital, as it is accompanied by more risk and the money is returned more slowly. For this reason, however, it is suited for a wider utilization of milk, since the manufacture can be stopped at any time without disadvantage, and the preparation of butter and the manufacture of skim-milk cheese can be substituted. When cheeses are sold off the farm, a not inconsiderable portion of mineral salts, consisting chiefly of calcium phosphate, is removed. If all the milk in a dairy be made into cheese, the value of the whey which is thus obtained may be estimated at one pig for seven to eight cows.

The inhabitants of Switzerland, who have for many hundreds of years produced an amount of milk in large excess of that which they can themselves consume, were early forced to utilize this excess by making it into cheese, since they could find, neither in their own country or in the neighbouring ones, the necessary market for the large quantities of butter which they manufactured therefrom. Hitherto—as, indeed, it is at present—the demand for butter in Switzerland and in South Germany has been much less than in North Germany, which is partly due to climatic conditions, and partly to the method in which bread-fruits have been used. Helped by the very favourable conditions which exist for the manufacture of the fatty cheeses, they have brought the manufacture of what is the finest and most highly-prized cheese, namely, the Emmenthaler, to great perfection.

In the manufacture of the finest soft cheeses, of different kinds, the French nation are unexcelled. The preparation of French table cheeses demands a great deal of care, a great deal of trouble, and attention to a large number of details; while skill is also required in a minor degree. It is more the work of women than of men, and the manufacture is not

only conducted in many small agricultural districts, but also, on account of the demand for this kind of cheese, it is made in factories on a large scale.

Other kinds of cheese of a less fine flavour are the Dutch and the English fatty and hard cheeses, the Edam and Gouda, made in Holland, in the marsh districts, and the Cheshire and Cheddar, which are made in England, in the districts specially suited for the manufacture of the cheese, chiefly in small and middle-sized dairies. Cheddar cheese is also made in large quantities in the United States. This kind of cheese is not only popular in its mother country, but in the colonies of Holland and England across the seas. The demand in the colonies is so great that the English production is far from adequate to the demand, and these cheeses are chiefly imported from North America. Owing to the conditions prevailing in North America, the fat cheeses are made on a large scale. As the manufacture of cheese in North America is nowhere carried on under especially favourable natural conditions, and is therefore uncertain in its result, the practice has been long tried of allowing the milk to become sour in the milk-vat, in order to increase the percentage of bacteria in the cheese, and thus to favour its ripening.

142. The Utilization of Milk in Different Countries.—Wherever cattle are kept, the rearing of calves, which only requires, comparatively speaking, a small portion of the milk, is carried on in addition to the other uses to which milk is put. The rearing of calves requires a large amount of capital, which is only slowly turned over, and as it involves much care and skill, it is better suited for large than for small farms. In the husbandry of districts of flat land in which milk-cows are kept in restricted numbers only, the rearing of calves is carried on with success, in addition to the manufacture of butter. On the other hand, in countries which are well suited for the keeping of cattle, the rearing of calves, in addition to other methods for the utilization of milk, is practised, and this custom, from an economic point of view, justifies itself. In countries where there is no lack of valuable cattle suitable for the purpose of rearing, young cattle are always reared. Here and there, however, in isolated districts, highly favourable conditions obtain for utilizing milk, and it would be a great economic mistake not to take advantage of them. The result is, that in all countries specially adapted for live stock, it is not possible to draw sharply-defined districts suited for different methods of utilization, and it is interesting to note in this connection that, on the whole, a higher return is

obtained by natural variation than would be the case if the entire population were set down to one branch of dairying. We find in Switzerland, that in addition to the rearing of live stock, and to the manufacture of butter carried out on a small scale, on the hill lands where rich pasture exists, an actively conducted and very remunerative manufacture of cheese is carried on; and in Holland, in addition to the rearing of calves, and a considerable manufacture of butter, we also find that not only is an excellent trade in the manufacture of cheeses carried on, but also in the fattening of animals on pastures. Similar conditions are found in the province of Schleswig-Holstein, in its different parts. In any country in which the different branches of dairying are found existing, developed to a natural degree, one is in a position, according to the state of the markets, to extend or to limit now the one or now the other branch of the dairying, so as to make the receipts at all times as high as possible.

143. Calculations for the Different Methods of Milk Utilization.—Under certain definite suppositions, and provided that on an average 1000 kilos. of milk, containing 3·3 per cent of fat, are at disposal daily, the following is the value of a kilo. expressed in pfennig, and also the expense of treating a kilo.:—

	Nett Proceeds.	Expenses.
(1) Sale of milk for direct consumpt, ...	15·52	4
(2) Fattening of calves with milk, ...	10	3
(3) Manufacture of whole-milk soft cheese,	12·75	1·5
(4) Preparation of whole-milk hard cheese,	11·71	1·25
(5) Deepsetting system, and the manufacture of butter and half-fat soft cheeses, ...	10·25	1·25
(6) Deep setting system, and the manufacture of half-fat hard cheeses, ...	10·01	1·25
(7) Treatment with centrifugal machine, and the manufacture of butter and skim-milk brick-shaped cheeses, ...	9·26	2·3
(8) Treatment with centrifugal machine, and manufacture of butter and skim-milk hard cheeses, ...	8·16	2·30
(9) Treatment by centrifugal separator, and the fattening of calves with skim-milk,	8·72	2
(10) Treatment with centrifugal separator, and feeding of swine with skim-milk,	7·89	2
(11) Deep setting system, the manufacture of		

	Nett Proceeds.	Expenses.
butter and skim-milk brick-shaped cheeses, ...	9·73	2
(12) Deep setting system, the manufacture of butter and skim-milk round cheeses,	10·04	2
(13) Deep setting system, manufacture of butter, and feeding of calves with skim-milk, ...	8·46	1·7
(14) Churning of milk, and manufacture of sour-milk cheeses, ...	9·69	2
(15) Churning of milk, and the manufacture of sour curd, ...	9·03	1
(16) Churning of milk, and feeding of pigs with butter-milk, ...	7·79	1

Of the nett proceeds realized, the following shows the amounts obtained by the various products:—

In the case of the manufacture of whole-milk cheeses, ...	by cheese,	80 to 94 %,	on an average	87 %.
	by bye-products,	20 „ 6 „	„	13 „
In the case of the preparation of butter and half-fatty cheeses, ...	by butter,	22 „ 24 „	„	23 „
	by cheese,	67 „ 69 „	„	68 „
	by bye-products,	8 „ 10 „	„	9 „
In the case of the preparation of butter and skim-milk cheeses, ...	by butter,	58 „ 79 „	„	69 „
	by cheese,	13 „ 34 „	„	24 „
	by bye-products,	5 „ 9 „	„	7 „
In the case of the preparation of butter, along with the feeding of calves and pigs, ...	by butter,	68 „ 83 „	„	76 „
	by bye-products,	17 „ 32 „	„	24 „

According as one makes either half-fat or skim-milk cheeses, or carries on the fattening of animals in addition to the manufacture of butter, the proceeds obtained from butter in the above-mentioned examples, which furnish data for the calculation, will amount to 23, 69, or 76 per cent. As the price obtained for milk depends upon the prices of its products, and as the prices of butter and cheese, as well as bacon and veal, vary in the course of time within wide limits,

it is obvious that the value of a kilo. of milk in the various methods of utilization is not to be found in the individual figures themselves, but rather in the proportion they bear to one another.

To illustrate the foregoing statements, we may take an example or two:—

(1) *Sale of Milk for Direct Consumption.*—If a litre of milk can be sold for 20 pfennig, and the cost connected with the sale amounts to 4 pfennig, then the kilo. of milk will realize 15·52, and the litre 16 pfennig.

The calculation of the weight of the milk from its measure is here based, as it is in all the following cases, on the assumption that the specific gravity of the milk, at 15° C., is 1·0315.

(2) *Manufacture of Fatty Soft Cheeses.*—There are so-called Remoudou cheeses, which are sold in a ripe condition at 1·2 marks per kilo. If the cheese loses in the store, before it is sold, 30 per cent of its weight, the value of the fresh cheese can only be placed at ·84 marks per kilo.

100 kilos. of milk yield—

Cheese, ...	16 kilos	@ ·84 marks	=	13·44 marks.
Whey, ...	81 ,,	,, ·01 ,,	=	·81 ,,
Loss, ...	3 ,,			
	100 kilos.			14·25 marks.
		Expenses,		1·50 ,,
				12·75 marks

1 kilo. of milk thus produces 12·75 pfennig, and a litre 13·14 pfennig.

(3) *Preparation of Fatty Hard Cheeses.*—Fatty hard cheeses, prepared in the Swiss method, possess, in a ripe condition, a market value of 1·4 marks per kilo. If the cheese lose in the store before its sale 15 per cent of its weight, the value of the fresh cheese can only be put at 1·19 marks.

100 kilos. of milk produce—

Cheese, ...	9·00 kilos.	@ 1·19 marks	=	10·71 marks.
Whey butter,	·75 ,,	,, 1·60 ,,	=	1·20 ,,
Butter-milk,	1·20 ,,	,, ·02 ,,	=	·02 ,,
Ziger cheese,	2·50 ,,	,, ·16 ,,	=	·40 ,,
Whey, ...	84·55 ,,	,, ·0075 ,,	=	·63 ,,
Loss, ...	2·00 ,,			
				12·96 marks.
	100·00 kilos.	Expenses,		1·25 ,,
				11·71 marks.

1 kilo. of milk produces 11·71 pfennig, and the litre 12·07 pfennig.

(4) *Ice Treatment—Preparation of Butter and Half-fat Hard Cheeses.*—Half-fat hard cheeses, made according to the Swiss method from evening milk which had been creamed after treatment with ice, and of whole morning milk, the whole being treated after standing for twelve hours, possess a market value when ripe of 1 mark per kilo. If the cheese lose 12 per cent of its weight in the store, the fresh cheese can only be valued at ·88 marks per kilo.

100 kilos. of milk produce—

Cheese, ...	8·50 kilos.	@ ·88 marks	=	7·48 marks.
Butter, ...	1·30 ,,	,, 2·10 ,,	=	2·73 ,,
Butter-milk, ...	2·60 ,,	,, ·02 ,,	=	·05 ,,
Ziger cheese,	2·40 ,,	,, ·16 ,,	=	·38 ,,
Whey, ...	83·20 ,,	,, ·0075	=	·62 ,,
Loss. ...	2·00			
	100·00 kilos.		=	11·26 marks.
		Expenses,	=	1·25 ,,
				10·01 marks.

1 kilo. of milk fetches 10·01 pfennig, and 1 litre 10·3 pfennig.

In this case 1·1 kilo. of cream butter, and in addition ·2 kilos. of whey butter, that is, a total of 1·30 kilos. of butter, are obtained. If cream and the whey cream be together made into butter, a butter of inferior quality is obtained of which the kilo. can no longer be valued at 2·2 marks, but only at 2·1 marks.

According to numerous carefully collected data, the cost of collecting 200 cart-loads of ice of 30 cwts. weight, may be put at 375 marks. If the ice-house necessary for keeping this ice be estimated as costing 2000 marks, and 15 per cent of this amount be allowed yearly for interest and depreciation, that is, 300 marks per annum, the total cost for ice may be stated at 675 marks. If the 300,000 kilos. of ice in the course of time be diminished one-half, and if there be used, on an average, in cooling 1 kilo. of milk, 5 kilos. of ice, the amount of milk cooled by the ice will amount to 300,000 kilos., and the cost will amount to ·225 pfennig per kilo. of milk. This calculation, which for the sake of simplicity may be roughly put at ·3, is included in the 1·25 pfennig which has been included as the cost of treatment per kilo. of milk.

144. Keeping of Books.—Dairy accounts are kept practically in all dairies in Germany, in some cases in an elaborate, in others in a perfunctory manner. In almost no case are none kept. As each business becomes extended and developed, the more obligatory does

the systematic keeping of books become, and in the case of public companies, according to the law of May 1st, 1859, special books, which have to be audited at least every two years by an impartial auditor, must be carefully kept. The proper manner of keeping books for dairy purposes is easily learned.

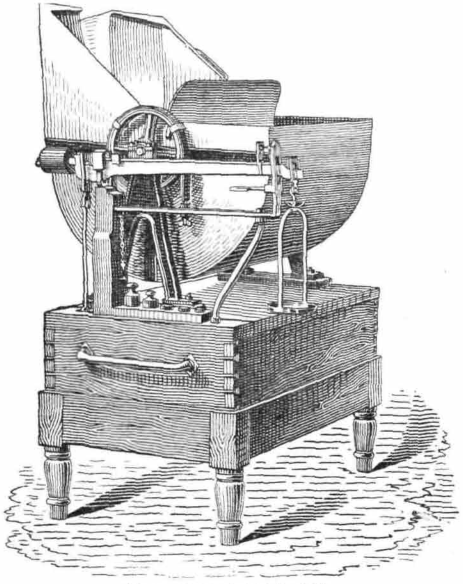


Fig. 83.—Machine for Weighing Milk.

In a good system of book-keeping, not merely milk, but also all milk bye-products, should be entered, not according to volume, but according to weight (figs. 83 and 84). The ½ kilo. or pound has been chosen as the unit of weight in all technical calculations in dairying, since the kilo. is too large for this purpose.

In book-keeping, an exactly accurate account of all the items connected with the obtaining and treating of milk must be noted.

In the first place, a record should be kept of the annual yield of milk per cow, its average percentage of fat, and the annual yield of butter, *in order to form a basis for the economic valuation of the* individual cows. Further, the books must exactly indicate how much of the milk supplied to the dairy is used, and how much is

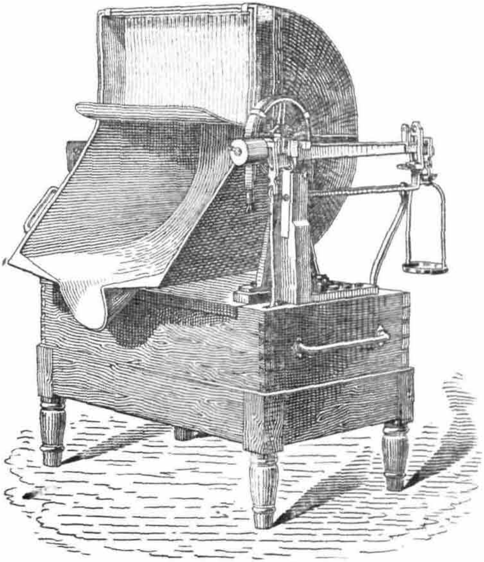


Fig. 84.—Machine for Weighing Milk.

sold; how much is treated, and what amount of bye-products are obtained; what loss the bye-products involve, and what value they fetch. In addition, calculations should be made with regard to all the bye-products, by which the yield, both with regard to quality and quantity, as well as the amount of working expenses, is influenced. Records should also be kept of the temperature of the milk, cream, and skim-milk; and, in the case of cream-raising, particulars

as to the entire course of creaming should be noted. In cheese-making, particulars should be noted with regard to the use of rennet and cheese colours, the duration of the thickening period, the treatment of the curd, and the temperature and the relative moisture in the cheese store-room. Where ice is used for different purposes, careful records should be kept, and particulars as to the weather and other conditions, which do not admit of enumeration in this place, should also be taken.

For the purpose of determining the milk record of the year, milk registers may be used, in which the weekly results of the testing of samples should be entered. The percentage of fat in the milk may be determined once every week.

If the figures with regard to the treatment of milk are perfectly recorded, it is possible to determine daily, weekly, monthly, or yearly the success of the treatment of milk, either on an average or in individual cases.

For example, if one finds that 100 kilos. yield—

Cream, ...	16·68
Skim-milk, ...	82·75
Loss, ...	·57
	100·00

by dividing 16·68 into 100, the result will be 5·995, a number which indicates how many parts by weight of milk correspond to 1 part by weight of cream. This number is used for calculating the yield of butter from milk by weight, in which the cream coming from the milk to be treated is not all made into butter. If, for example, 10 kilos. is all that is used of the entire quantity of cream obtained, the quantity of milk treated must be diminished by $10 \times 5{\cdot}995$, which equals 59·95, in order to obtain the quantity of milk used to get the amount of butter.

For example, it is found that 100 kilos. of cream yield—

Butter, ...	20·38
Butter-milk, ...	77·70
Loss, ...	1·92
	100·00

To these, 100 parts by weight of cream, as we know, correspond 599·5 parts by weight of milk, according to which we find that for every part by

weight of butter $\frac{599 \cdot 5}{20 \cdot 38} = 29 \cdot 41$ parts by weight of milk correspond, or for every 100 parts by weight of milk $\frac{100}{29 \cdot 41} = 3 \cdot 4$ parts by weight of butter correspond. If the skim-milk be made into skim-milk round cheeses, we further know, for example, that 100 kilos. of skim-milk yield on an average—

Cheese, ...	7·96
Whey, ...	89·61
Loss, ...	2·43
	100·00 kilos.

From this we find that for the preparation of one part by weight of fresh cheese, $\frac{100}{7 \cdot 96} = 12 \cdot 56$ parts by weight of skim-milk are required. From all the above-mentioned figures we finally discover that 100 kilos. of milk on an average yield—

Cream, ...	16·68 kilos.	Butter, ...	3·40
		Butter-milk, ...	12·96
		Loss, ...	·32
Skim-milk, ...	82·75 „	Cheese, ...	6·59
		Whey, ...	74·15
		Loss, ...	2·01
Loss, ...	·57 „	Loss, ...	·57
	100·00 kilos.		100·00 kilos.

The total loss, therefore, in treating 100 kilos. of milk amounts to 2·90 kilos. If the gross value of the individual products and bye-products be known, it is easy to calculate the gross value of a kilo. of milk from this.

In the preparation of fat cheeses, as, for example, in the preparation of Emmenthaler, it is found on an average that 100 kilos. of milk yield—

Cheese, ...	9·00
Whey butter, ...	·75
Butter-milk, ...	1·30
Ziger cheese, ...	2·50
Whey, ...	84·60
Loss, ...	1·95
	100·00 kilos.

For every one part by weight of fresh cheese, there is accordingly required $\frac{100}{9} = 11 \cdot 11$ parts by weight of milk.

The actual yield of butter obtained may be easily tested, as soon as the average percentage of fat of the milk treated is known, by means of a formula, to see whether it may be regarded as satisfactory or not. If the quantity of butter-milk obtained from 100 kilos. of milk be indicated by the letter B, and the percentage of fat of the milk, the skim-milk, and the butter by f, f^1, and F, and the quantity of cream yielded per 100 parts by weight by the letter R, and the yield of butter by the letter A, the following formula will be obtained:—

$$1\ \mathrm{B} = \frac{\mathrm{A}}{\mathrm{F}}\left(f - f^1 \times \frac{(100-\mathrm{R})}{100}\right).$$

Thus, if to A, F, and f^1 the values of 97 per cent, 84 per cent, and ·25 per cent be given, which may be regarded as what should be easily obtained in practice by careful work, and which, therefore, should be regarded as satisfactory, and to R the value of 15 per cent, we find the following:—

$$(\mathrm{I.})\ \mathrm{B} = 1{\cdot}155 \times f - 0{\cdot}245.$$

For f will be found 3·30 per cent, and for B 3·57 per cent; that is, one *must obtain from 100 kilos. of milk 3·57 kilos. of butter.* If, then, the calculated quantity of butter is found to be more than that actually obtained by ·1 or more per cent, there is a mistake made somewhere, either in the creaming or in the churning. In order to discover where this mistake is, the percentage of fat in the skim-milk and in the butter-milk must be determined, so that the correct measure obtained in proper working should not be exceeded.

If the common formula (1) for f be worked out, the result is as follows:—

$$(\mathrm{II.})\ f = \frac{\mathrm{B} \times \mathrm{F}}{\mathrm{A}} + f^1\ \frac{(100-\mathrm{R})}{100}.$$

If, again, the values for A, F, f^1, and R be again the same, as given above, the following will be the result:—

$$(\mathrm{II.})\ f = 0{\cdot}866 \times \mathrm{B} + 0{\cdot}2125.$$

From this formula, provided the work be carefully and properly carried out, it is possible to calculate, with approximate accuracy, the average percentage of fat in the milk, when the yield of butter is known.

Finally, if we indicate the percentage of fat in the cream by the letter f^2, the following formula will be obtained:—

$$(\mathrm{III.})\ f^2 = \frac{100}{\mathrm{R}} \times f - f^1\ \frac{(100-\mathrm{R})}{\mathrm{R}},\ \text{or}$$

$$f^2 = \frac{100 \times \mathrm{F}}{\mathrm{A} \times \mathrm{R}} \times \mathrm{B};$$

and if the above-mentioned values be given to A, F, f^1, and R, the result is as follow:—

$$(\text{III.})\ f^2 = 6{\cdot}667 \times f - 1{\cdot}4167, \text{ or}$$
$$f^2 = 5{\cdot}773 \times \text{B}.$$

For calculating B from f or f^2:—

$$\text{B} = 1{\cdot}155 \times f - {\cdot}245, \text{ and } \text{B} = {\cdot}1732 \times f^2.$$

For calculating f from B or f^2:—

$$f = {\cdot}886 \times \text{B} + {\cdot}2125, \text{ and } f = {\cdot}15 \times f^2 + {\cdot}2125.$$

For calculating f^2 from f or B:—

$$f^2 = 6{\cdot}667 \times f - 1{\cdot}4167 \text{ and } f^2 = 5{\cdot}773 \text{ B}.$$

With the help of these formulæ, it is possible to calculate from any one of the magnitudes F, f^1, A, and R, what the rest are.

145. The Payment of Milk according to Weight and Composition.— Milk which is used for direct consumpt is sold at present, as is well known, according to measure, and not according to composition. Indeed, it is sold without any reference to its composition—a fact which is in the interest of the seller, but not in that of the purchaser. On the other hand, milk which is destined to be worked into milk products has been sold since about 1880 at so much per kilogram, according to its composition. This arrangement has become, from an economic point of view, all the more urgently desirable the more the trade has improved, the keener the competition in the production of butter and cheese has become, and the more convenient the conditions are for the working of large quantities of milk. It has only been adopted since the methods for the determination of fat in milk have improved so much that the fat can be determined in a short time, with all the accuracy that is required, without the aid of a chemical balance.

The exact determination of the price of a kilogram of milk, according to its composition, and the amount of substance it will yield when converted into either of its bye-products, is very difficult, and indeed hardly possible to calculate. The more accurately the manufacture is conducted, the more trouble and expense has to be incurred, and, when there is taken into account in this connection economic considerations, one is forced to rest contented with obtaining a good result without striving to reach the best possible.

The first consideration in determining the utilization value of milk is an exact knowledge of its solids. It is scarcely of any practical value to obtain the composition of milk in all its constituents, since its value is almost entirely determined by its percentage of fat and casein, and only to a slight extent by its mineral constituents. But even the determination of the caseous matter, in addition to the fat, in order to estimate its value for the manufacture of fat and skim-milk cheeses, is only of advantage in a few cases. It involves far more than double the expense caused by the determination of the fat alone. At present, therefore, it is only customary to obtain the percentage of fat in milk, and to calculate the value from that.

Obviously, if the selling price is to be determined in the dairies of the different suppliers of milk by the percentage composition of the milk, it will be necessary to estimate daily the percentage of fat in each consignment, since it is only by this method that the true average percentage in the milk of the different suppliers for the period for which payment is made can be determined. This in practice, owing to the great expense involved, is at present scarcely feasible. For this reason, it is only customary to examine the milk of each customer several times in a month for its percentage of fat, and to calculate from the figures thus obtained an average value, which obviously will not exactly agree with the true average value. The oftener per month the investigations are undertaken, the nearer will the true average value be arrived at; and the frequency with which they are made depends on the degree of approximation which those interested deem desirable. A periodical examination of the milk should be made not less than once a week.

If the amount of the average percentage of fat of the milk obtained during the month from each supplier be known, as well as the average percentage of fat in the whole quantity of milk worked during the month, and if the question be how to fix a price for a kilo. of milk from the different suppliers, and the monthly price to be paid, several methods may be adopted, according as to whether, as is the case in dairy companies, the question is as to the division of a sum of money, or, as is the case with the dairy-farmer and the owners of collecting dairies, the proper adjustment of the price to be paid for the milk, to that of the price of the butter. We may take the first case:

(1) *Payment of Milk in Dairy Companies in which Fatty Cheeses*

are made.—In the treatment of milk for the manufacture of fatty cheeses, the idea is not excluded of taking the division of the proceeds according to the amount and the average percentage of fat o the milk consignments. This procedure can be justified, in certain cases at any rate, by the fact that the yield of cheese is not dependent exclusively on the percentage of caseous matter in the milk, and that it is not always proportional to the percentage of fat in the milk; but that, for the most part, the milk richest in fat yields the largest amount of cheese, and vice versa, and that in the case of the percentage of caseous matter in the milk remaining the same, the yield of cheese both in quality and quantity is greater, the greater the percentage of fat. Indeed, there are kinds of cheeses which turn out best if the amount of fat in proportion to caseous matter does not exceed a certain amount, and in the preparation of which, therefore, milk very rich in fat is scarcely much more valuable than milk of an average percentage of fat. In this case, it may be doubted whether perchance a division of the proceeds simply according to the quantity of the milk supplied by the individual shareholders would not be best. The author is not aware whether payment of milk by weight and composition has been introduced into dairy companies in which only fatty cheeses are made.

In no case have reliable experiments, with regard to the influence which a change in the composition of milk exercises on the yield of fatty cheeses of different kinds, been made, and up to the present time data are not available which permit of the further theoretical consideration of the question.

(2) *Payment of Milk in Dairy Companies which have a Limited Trade.*—By a limited trade we mean the case where the milk which is delivered is made into butter, and where all the bye-products in varying amount are sent to the shareholders. By this method it was formerly attempted to divide the monthly proceeds, according to the amount of milk, and the average percentage of fat of the milk consignments.

146. Structure and Arrangement of a Large Dairy.—During the last fifteen years, in the course of which a large number of dairy companies and extensive agricultural enterprises have sprung into existence, the arrangement of dairies in our several districts has been materially improved. Not only has the necessity been demonstrated for providing all these requirements which have shown themselves in course of time to be important, but the opportunity

has been found to collect the necessary experience for carrying this out in a suitable manner. It is now recognized that every properly-equipped dairy should possess an open healthy site, should be supplied with good and pure water, and with ice apparatus, that its rooms should have a flooring impervious to water, and that all waste water should find easy exit. It is also necessary that the individual rooms should be easily heated and aired when desired, and should be supplied throughout with pipe connections supplying always steam, or cold or hot water, and that there should both be a counting-house, and a laboratory for the examination of the milk. A further requirement is, that the individual rooms should not merely be of a proper size, with regard to area and cubic capacity, but should also be arranged in such a way that the treatment of the milk can be carried on in the simplest possible manner, and that in the preparation of the chief products, unfavourable influences should not make themselves apparent. Finally, it is desirable that the milk delivered, as well as the bye-products produced by its treatment, should be dealt with by the assistance of gravity or other natural forces on the place of delivery, and that manual labour should be employed in their manufacture to as slight an extent as possible.

Figure 85 shows the method of arrangement of a modern farm, fitted with machinery for utilizing a Danish centrifugal separator. From the part (A) the milk is borne in cans (B) to the weighing-machine (C), into the receiver of which it is poured. After it is weighed, the milk flows first into the collecting-vat (D), and then through the tube (*d*) and the warmer (E) into the separator (F). The cream then goes into the ascending tube (G) into the scum-collector (H), flows through the Pasteurizing apparatus (I) and over the cooler (J), and through the tin gutter (*j*) into the cream-vat (K). The skim-milk is conducted through the second ascending tube (L), and from there into the open gutter (*l*) and then into the scum-collector (M), and through the Pasteurizing apparatus (N) and over the cooler (O), and into the collecting-vat for skim-milk (P). From the vat (P) the skim-milk is filled into the skim-milk cans (R) standing on the balance (S), and then it is furnished again to the milk suppliers. If the skim-milk be made into cheese, it is permitted to run from the gutter (*l*) into the cheese-vat.

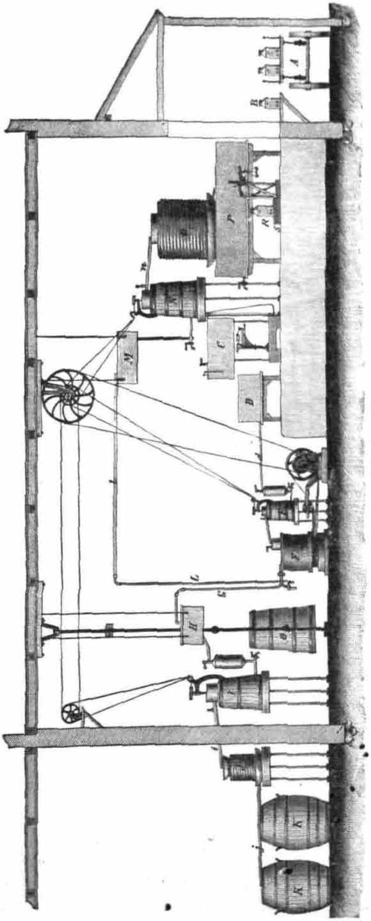


Fig. 85.—Model of Large Dairy.

CHAPTER VIII.

MARGARINE AND MARGARINE CHEESE.

147. **Margarine.**—The manufacture of margarine as at present carried on has as little to do with dairying as the manufacture of margarine cheese. It is, however, desirable to say a few words on its nature, as both these products enter into competition with dairy products, and because the fraud connected with the trade in margarine, which is growing in extent every year, and for the purpose of checking which special legislation has become necessary, not merely affects the dairying industry, but the whole agricultural industry.

Before the year 1887, margarine was universally known both in Germany and in Austria as butterine. The preparation of margarine was first carried out in France. Shortly before the Franco-German war in 1870, M. Mège-Mouriès, a French chemist, was requested by the Emperor Napoleon III. to investigate the question of obtaining a good cheap substitute for butter, for the French Marines, and for the poorer inhabitants of Paris. The animal fats of all domestic animals used for meat are not suited for use for kitchen purposes, since for many purposes they are partly too hard and friable, and partly too soft and greasy, and since all of them possess a peculiar smell and flavour, probably caused by small quantities of volatile fatty acids. The above-mentioned chemist quickly carried out his commission in an excellent manner, and discovered by experiment a cheap butter substitute possessing many excellent qualities, and capable of being prepared in a simple manner from the best ox-tallow. According to a regulation of the Paris Health Council of 12th April, 1872, the public sale of the new fat, which was named margarine-mouriès, was sanctioned under the condition that it was not to be brought into commerce under the name of butter. According to the process of Mège-Mouriès, a portion of stearin separated from the best kidney fat is converted into a fat which possesses properties similar to butter, and which has practically lost the peculiar flavour of raw fat. This method thus renders the use of the fat of the animal

body possible, and has given rise to a new fat, the so-called oleomargarine, which is capable of more extensive and varied uses than the raw material from which it is derived. It is this idea which gave rise to the preparation of margarine, a thoroughly wholesome substance, against which nothing can be urged, and which indeed should be welcomed, since it serves a most useful purpose.

The preparation of the new fat rapidly extended from France, and became at first established in America, Germany, and Austria; then in Russia and other countries. Up to the end of 1880 nearly all the so-called artificial butter sold in Europe was prepared according to the excellent process of Mège-Mouriès. As the new fat was in its original state truly an excellent cooking-fat, containing a somewhat larger percentage of fat, and therefore more economical than butter, and as it possessed better keeping qualities, and also excelled, both in quality and appetizing flavour, the common peasants' butter, which was placed on the markets in great quantities, its use steadily increased. Frankly, what helped to rapidly extend the use of the fat was the fact that the name butterine, which had been given to it, was very commonly confused with butter, and it was introduced into commerce in large quantities as butter.

The large extension of the manufacture of margarine had the result that the raw material which at first was solely used in its manufacture, namely, fresh ox tallow, was soon no longer procurable in the necessary quantity. According to the experiments carried out at the butter factory, opened in the year 1873, at Leising near Vienna, 100 kilos. of raw tallow yielded on an average 22 kilos. of butterine. At the central cattle slaughter-house at Berlin in 1885, there were killed yearly an average of 150,000 head of cattle. If it be assumed that 90 kilos. of raw tallow was obtained per head, taking each animal at 600 kilos. of live weight, and that this yielded 20 kilos. of butterine, we find the result to be, that from the fat of 150,000 head of cattle 3,000,000 kilos. of butterine could be made; or, broadly speaking, about as much as was turned out at that time from any one of the larger factories in a year. The result was that the Mège-Mouriès process of butterine manufacture was abandoned. In order to increase the yield of oleomargarine, obtained by first melting the raw fat at a temperature of 45° C., a temperature of 60° C. was applied, and in addition the stearin was subjected to greater pressure than was formerly the case. The result was that 100 kilos. of raw tallow yielded 60 to 62 kilos. of oleomargarine instead of

20 kilos., which was formerly obtained, but the product was of an inferior quality. It was richer in stearin, and possessed a higher melting point (40° to 43·4° C.) in the poorer sorts, but a firmer consistence. The other difficulties which were met with in the more extended use of this product were sought to be overcome. Thus, in order to lower its melting point and to improve its condition, the cheaper kinds of plant oils were employed, such as earth-nut oil, cotton-seed oil, walnut oil, rape oil, the poorer sorts of olive oil, the oil of fenugreek, cocoa oil, cocoa-kernel oil, sesame oil, &c. In short, as an increase in the production of oleomargarine from ox tallow was no longer possible, manufacturers were forced to utilize other kinds of fat in the manufacture of oleomargarine, which offered little difficulty, since, by the simultaneous use of plant oils, fats of firmer consistency could be used.

The nature of the different kinds of fat which were used, or supposed to be used, can be seen from the patents taken out in connection with this article. In addition to ox tallow the following were used:—Veal tallow, bacon fat, goose fat, slaughter-house fat, stearin, fat from soap-boiling manufacturers, and fat from flaying-houses, a bad discoloured fat possessing a disagreeable smell, and purified by treatment with strong mineral acids. At present the larger part of the raw material of oleomargarine which is treated by the margarine factories is no longer obtained in Europe, but by import from North America, and probably from Australia, that is, from sources not under inspection. This is not unimportant. Through certain infectious diseases the fatty material of sick animals may undergo changes which render very dangerous to mankind the consumption of the fat obtained from them. By the careless preparation of oleomargarine, there is a possibility that the spores of animal parasites, and, where traces of the muscle substances are contained in the fat, even trichiniæ, may be introduced into the margarine. This is all the more important, since in the preparation of oleomargarine a temperature of at most 65° C. is employed, a temperature which cannot be regarded as invariably effecting the destruction of the above-mentioned organisms. Although up to the present no case of illness has been proved to be directly due to the partaking of margarine, this does not guarantee that serious outbreaks of illness might not suddenly arise, due to the use of bad margarine. The use of plant fats in the preparation of margarine is also open to objection. Plant fats consist of different mixtures of fats from that

of animals, and are, as common experience has shown, less easily digested than the latter.

It goes without saying, that attempts have been made, in order to promote its sale, to make margarine as attractive as possible. There is no reason, however, on this account, for rendering the new fat similar in external appearance to butter, or for bringing it on the market in a similar form and packed in the same way as butter. The great resemblance of the prepared animal fats to butter has always this disadvantage, that it opens the way to fraudulent practices, and has thus a tendency to destroy the honest character of the sale. The possibility of fraud was formerly increased by the universal practice of calling margarine by the name of butterine; that is, by a title which was only justified by the appearance of the margarine, but which was otherwise strained on account of the fact that not only was the chemical behaviour of the margarine, but also its mechanical texture and fundamental condition, different from that of butter.

Of more importance still than the use of the word butterine, was the manufacture of mixtures of margarine and butter, and the manufacture of mixed butters, which were commonly used in the years 1884 and 1885. These different titles indicated, clearly enough, the fraudulent intention which underlay them. It is hardly necessary to add that no improvement in the food is effected by the mixing of margarine with good butter. The mixture of butter with foreign fat is practised solely for the purpose of increasing the value of the very cheapest fat by the addition of good butter, so that it may take the place of butter to a large extent, and that at a relatively higher price; or for the purpose of passing it off in the market as butter. For these reasons this practice must be regarded as an attempt to create a new and lucrative industry, at the expense of the dairy industry, and of the less wealthy portion of the public.

Thus, in the course of time, the manufacture of margarine has departed more and more from the healthy basis on which it was started in 1870, and has threatened to become, to a serious extent, a parasitic industry. It has placed the manufacture of butter at a disadvantage, given an impetus to the perpetration of fraud, and has thrown on the market a large quantity of food, the origin of which is a mystery, and which everyone has a right to regard with distrust. About ten years ago measures were adopted in most countries where dairying was in an advanced state, Holland excepted, to free the

new industry from its unhealthy accretions, and to place it in its former position. German agricultural interests effected, not without much trouble, the passing, on July 12th, 1887, of a law dealing with the sale of butter substitutes. This law came into force in October, 1887. If it did not entirely meet all the necessities of the case, it nevertheless furnished, when stringently and watchfully carried out, and in combination with the law of 14th May, 1879, *dealing with the consumption of foods and condiments*, and the conditions of their use, an important protection to agriculture and to the public.

With regard to the development of the margarine industry in the United States of North America, little is known to the author of a detailed and definite nature. It would seem that the manufacture of margarine, since its commencement, has been carried on with less care than in Europe. In the latter case the manufacture was carried on practically according to the process of Megè-Mouriès, and according to a process patented by Mr. Paraf on April 8th, 1873, after Hortiny's specifications. The new food was not called margarine but butterine.

Soon after the discovery was made by Megè-Mouriès, attempts were made in various quarters, at first with little success, to introduce the manufacture of margarine into Austria-Hungary. The first attempt originated with an American, Benford, who came to Vienna in 1871, and who there exhibited samples of margarine, which were discovered to consist for the most part of butter. Subsequently a *Belgian, Ronstorff, general consul for the republic of Uruguay*, exhibited at the first dairying exhibition held at Vienna in 1872 on the 13th to 17th December, several samples of margarine which, according to his representations, were prepared from ox fat and milk. His attempts to start the manufacture of margarine on a commercial scale also failed. The first to introduce the manufacture successfully into Vienna was Mr. Sarg, the owner of the world-renowned soap factory at Leising. He built in Leising in 1873, with the help of a French engineer, a factory, which was opened in 1874, after the municipal authorities of Vienna had granted permission to sell the new fat under the name of *prima Wiener sparbutter*. The factory of Sarg was one of the first and best arranged of the large margarine factories started in Europe outside of France. It supplied margarine which had been prepared from fresh ox tallow, and which was prepared in an appetizing form. Among the many forms of

margarine which the author has had an opportunity of examining in the course of time, the *prima Wiener sparbutter* was the best.

In Holland, so far as the author is aware, no margarine is made, or, at any rate, sold as such. In that country the preparation of mixed butter, since the year 1870, has been developed to an extent which is found nowhere else. As long as the Dutch butter market is in existence, there will be no lack of dealers to mix the superior and the inferior kinds of butter, and produce an average saleable article, and thus make profit. Against the method of mixing, which is still carried on elsewhere, it is impossible to do anything. Butter has, however, been mixed with all sorts of fats, a condition of affairs which formerly only very rarely occurred. At the time of the Franco-German war, when the demand for butter became greater and greater in Holland, inferior butter, Galician, Russian, and Finnish butter, at first mixed with milk and starch solution, and subsequently also with fats and oils of different kinds, were all worked together by a butter-worker and sold as butter or mixed butter. The discovery of Megè-Mouriès, which was either not at all, or only to a very slight extent, utilized in Holland, merely helped to further develop the mixed butter industry, by furnishing it with acceptable raw material. From the use of butter-workers the business advanced to the manufacture on a factory scale, and factories were erected to mix butter with fats, oils, milks, and colouring matter in large butter-vats, at temperatures at which the fats in use melted. The proportions in which these raw materials were mixed were as follows:—15 to 35 of milk, 40 to 70 of margarine, 13 to 35 of oil, and from 0 to ·5 of butter. The better sorts contained, indeed, an addition of from 10 to 20 per cent of the best butter. The desired oily condition was imparted to the product by the addition of a considerable quantity of oil, according as it was desired to produce an article possessing a dull opaque substance, more of the nature of a salve, or a transparent wax-like material. This difference in the preparation accounts for the fact that the Dutch so-called artificial butter, which, both in a salted and unsalted condition, is placed on the market like butter, possesses no uniform chemical composition. From the above short description, it will be seen that the preparation of good margarine from fresh animal fat, obtained from healthy animals, and without the addition of milk, cream, or butter, is a useful and beneficial discovery. It has had the effect of utilizing animal fats, and of rendering them capable of manifold application,

and has permitted of their being used for the middle and lower classes as a cheap cooking fat, and a good substitute for butter. Good margarine is quite capable of entering into successful competition with poor kinds of butter, but not with first-class butter, so that there can be no talk of a serious blow being dealt to the butter trade or to dairying through its use. Nothing can be objected against the preparation of margarine, as long as it is manufactured in such a way that the product is of an appetizing nature, and free from all unhealthy adulterants. Its manufacture is wholly justifiable, and no sensible man will deny the economic importance it possesses, in so far as it supplies a want, and furnishes a valuable public food.

The following paragraph gives the chemical composition of margarine and mixed butters of different sources:—

	French Margarine.	American Butterine.	Prima Wiener Sparbutter.	Hamburg Mixed Butter. 1st Quality.	Hamburg Mixed Butter. 2nd Quality.	Hamburg Mixed Butter. 3rd Quality.
Water, ...	12·56	11·25	10·69	10·25	9·61	8·08
Fat, ...	86·24	87·15	87·45	85·88	86·26	84·15
Other organic matter, ash and salt, ...	1·20	1·60	0·46	1·75	1·62	2·14
			1·40	2·12	2·51	5·63
	100·00	100·00	100·00	100·00	100·00	100·00

The percentage of insoluble fatty acids in the Wiener sparbutter, and in the Hamburg mixed butter, amount respectively to 95·59, 92·47, 93·58, and 93·96. In the investigation according to the Reichert method, the quantity used for the three Hamburg mixed butters was respectively 5·3, 2·8, and ·9 c.c. of the tenth normal alkali solution, and the specific gravity of the pure fat of the three samples of Hamburg mixed butter at 100° C. was respectively ·8618, ·8605, ·8601. The Wiener sparbutter was analysed by the author in 1887, and the others in 1886.

148. Margarine Cheese.—Margarine cheese was formerly known as melted cheese, oleomargarine cheese, and artificial cheese. It is now known as the kind of cheese which it imitates. While it was possible to say of the preparation of margarine that it originated in a proper idea, as was pointed out previously, and that it might be regarded as a beneficial discovery, so long as there existed a want that it could supply, and that it thereby justified its existence, it was difficult to say the same of the preparation of margarine cheese. No one can deny that the demand for butter exceeds that for cheese, and that it is a benefit for the poorer section of the people, who are

not able to buy the higher-priced butters, to have at their disposal, instead of bad butter, a good, healthy, and cheap substitute. But the demand for cheeses is, on the whole, by no means very great, and the already limited area for the manufacture of cheeses abundantly suffices for it. The demand for the finer kinds of cheeses is still comparatively brisk, but it is not so for cheeses of the medium and poorer kinds, such as skim-milk cheeses. In connection with the consumption of cheese, the taste of the individual is an important factor, and in large districts of Germany cheese is no longer a popular food. The reason of this is not due to the fact that there is a lack of good skim-milk cheeses, and that good cheeses have not been successfully prepared from milk which has been skimmed by means of centrifugal force. Where skill is not awanting, it is possible to make good skim-milk cheese possessing a piquant flavour. That this art has not yet become widely known cannot be doubted, especially in Middle and North Germany, but as the demand increases it will certainly be rapidly developed. In districts in which a taste for cheese is awanting, or where the people have not become accustomed to eating cheese, no market would be found for margarine cheese, even although—which is a doubtful point—margarine cheese excelled milk cheese in flavour. Nor can the small use of skim-milk cheeses be explained on the ground that they are too dear, since there have been times when the ½ kilo. of skim-milk cheese of good quality was, owing to a scarcity of demand, to be had for 15 to 20 pfennig, a price at which a similar weight of appetizing margarine cheese could not be supplied. It cannot therefore be asserted that the preparation of margarine cheese meets a pressing demand for public food, and that it has proved a benefit to the working classes.

It must be noted that cheese in which nitrogenous matter is present, along with a considerable amount of fat, is more easily digested than a skim-milk cheese poor in fat. This is certainly true, but it does not mean that margarine is required in order to increase the digestibility of skim-milk cheese. Whoever desires to render this cheese more digestible, through the addition of fat, would be better to do so by adding to his piece of cheese a piece of good bacon fat, and eating this along with it, than by buying it in margarine of a dubious origin.

Therefore it is not to be understood, after all that has been said, that the preparation of margarine cheese can be economically.

justified. Still less justifiable is the opinion that this branch of dairying can supply a want.

It has been further claimed that the utilization of skim-milk, which is found in some places to be very difficult to effect, would be greatly assisted by the manufacture of margarine cheese. If this be of any benefit, it can only be so in the same way as brandy is given to a person who has fainted, in order to bring him again to his senses. Margarine cheese manufacture is far more dangerous to the manufacture of cheese than the manufacture of margarine is to the production of butter, and there can be no greater example of short-sightedness than to expect assistance to the dairy industry, in its time of need, from the help of a manufacture which utterly destroys the cheese industry, and thereby strikes a blow at the entire dairy industry. On the side of the dairies which have already entered into contracts, it is asserted that the maximum value on an average is not reached, and that the margarine cheese industry threatens many results which would be highly disastrous to them. The disadvantages consist in that the whey assumes, in the course of a few hours, a very disagreeable smell, which is disadvantageous to butter, that on this account it loses much of its value as a food, and that it is not available for margarine manufacturing purposes, and that it is capable of inflicting a deleterious influence on the sale of butter. If more attention were given to the preparation of skim-milk cheeses, the value of skim-milk would be much more considerably increased than by the manufacture of margarine cheese. 100 kilos. of skim-milk will yield 10 kilos. of fresh skim-milk brick-shaped cheeses, and, at the same time, 87 kilos. of sweet whey, leaving a loss from the total weight of 3 per cent. If the cheese lose before its sale 25 per cent in weight, so that only 7·5 kilos. of cheese are sold, and if the kilo. of ripe cheese only fetches 36 pfennig, there is obtained from the cheese, $7{\cdot}5 \times {\cdot}36 = 2{\cdot}7$ marks.

The manufacturers of margarine cheese, naturally enough, oppose the attempt to apply to the article the title of oleomargarine, or fatted cheese, nor are such titles convenient for the public. For this reason, there has been nothing to prevent the artificial products in common use from appearing under the names of the different kinds of cheeses of which they are the imitation. The buyer is then no longer certain of procuring what he desires to purchase. Fraud is easily perpetrated and the whole cheese industry decays. It is for these reasons, without doubt, the case that this new department of dairying is of no

use, but on the other hand is only likely to do harm, and to render all attempts made to improve the skim-milk industry abortive.

It has been said, finally, that margarine cheese is neither intended nor will enter into competition with ordinary cheese, but constitutes a new food, and is perfectly independent of the dairy industry. The conception, which supports the opinion that an industry which has for its object the imitation of one of the chief products of dairying, will in no way effect dairying, is so obviously absurd, that it needs no further consideration.

The preparation of margarine cheese, or, as it was formerly called, artificial cheese, was introduced from the United States of North America. Artificial cheese was already made in that country as far back as 1878, from skim-milk which, after melted margarine or other fat had been incorporated with it by special apparatus, was manufactured into cheese, special precautions being taken on account of the unstable state of the emulsion. This artificial cheese was, from the very first, a source of annoyance to the American farmer, and met with very little support from the public. In the course of time the attempt was made to develop the industry, and to introduce it into Europe, where the manufacture was begun in many countries, especially in Denmark. In Germany it was first undertaken by A. M. Mohr, of Barnfeld in Ottensted in Holstein, who took the matter up, and who has during recent years made great attempts to set the margarine trade into active motion. As has already been pointed out, A. M. Mohr did not buy skim-milk cheese, but had the product manufactured in dairies in which were the necessary utensils. The apparatus for the incorporation of fat into the skim-milk were the emulsion machines, which have been very much improved in the last few years, so that it is possible to obtain a fineness of the fat division not even exceeded by that of the butter-fat in milk itself. The most extensively used of these machines are the Danish, and those of Dr. De Laval. Both machines are centrifugal machines, and respectively make 4500 and 7000 revolutions per minute. By means of these machines, there is made in the manufacture of margarine cheese, from a definite proportion of skim-milk and margarine, an emulsion which is known to the manufacturer by the name of artificial cream, and which is added to the skim-milk which it is desired to manufacture into cheese, in such a proportion, that for every 100 kilos. of skim-milk there are about 3 kilos. of margarine. Despite the extraordinary fineness of the division of the fat,

so long as it is melted, it rises very quickly to the surface of the cheese-vat, so that even when the coagulation-time is of the shortest possible duration, there is always a small portion of the melted fat lost to the margarine cheese. It is, of course, obvious that the best kind of fat, such as is employed in the preparation of butter substitutes, is not used, but inferior fat and refuse from the margarine factories. This fact is admitted by the manufacturer. In consequence of the fact that the fat, during the process of emulsification, is submitted to the high temperature of 60° C., and that it offers an enormously large surface to the action of the oxygen of the air, it is further deteriorated. The result is, as is often noticed in the manufacture of cheese in this way, that the whey remaining behind often after a few hours gives off a highly disagreeable smell. The manufacture of margarine cheese is far more troublesome than the manufacture of genuine cheese, and its value depends to a large extent on the quantity and condition of the fat added to the skim-milk. The author has formerly had many opportunities of testing and examining American cheeses, although he has never seen the Mohr products. According to reports in the dairy newspapers, they do not possess good keeping properties, and are very liable to mould. They are prepared usually according to the Cheddar method, but also according to the method employed in the making of Limburg, Gouda, and Edam cheeses, and even after the method of the Stilton. With regard to their flavour nothing can be said. In margarine bad fat can be very easily detected. In ripe margarine cheeses it is less easily detected. Anyone with a good appetite may enjoy this kind of cheese, but it is not a common taste. It is not suited for the tables of the rich. The manufacturers of margarine cheese must therefore find an outlet for their cheese chiefly among the poorer classes, and it is this portion of the public who must pay for the whole industry, without obtaining any advantage. Neither in Germany nor elsewhere is margarine cheese popular. Whether this is due to its quality, or to a healthy instinctive feeling on the part of the public, is doubtful.

A careful consideration of all the conditions of the trade proves the margarine cheese industry to be of a purely parasitic character. It benefits no one except itself, and grows rich at the expense of the poorer classes and the dairy industry. That there should be dairies which do not scruple to work in the interests of this industry, is as difficult to understand as it is lamentable.

CHAPTER IX.

EXPLANATION OF THE APPENDED TABLES.

149. In the preceding paragraphs different works and calculations have been referred to in the sections describing dairying, to illustrate which, calculation tables are either necessary or extremely desirable in the interests of economy of time. The number of tables which have been devised in the interests of dairying have in the course of time become so greatly increased, that it is impossible to publish all of them in a text-book. The author will consequently only give a few which are most frequently required for use.

Those given here are as follows:—

Table I. *Comparison of Fahrenheit, Centigrade, and Réaumur Thermometric Scales.*—The temperature can be converted from one scale into the other by the following formulæ:—

$$n^\circ \text{ F.} = \tfrac{5}{9}\,(n-32)^\circ \text{ C.} = \tfrac{4}{9}\,(n-32)^\circ \text{ R.}$$
$$= \cdot 555\,(n-32)^\circ \text{ C.} = \cdot 444\,(n-32)^\circ \text{ R.}$$
$$n^\circ \text{ C.} = \tfrac{4}{5}\,n^\circ \text{ R.} = (\tfrac{9}{5}\,n+32)^\circ \text{ F.}$$
$$= \cdot 8\,n^\circ \text{ R.} = (1\cdot 8\,n+32)^\circ \text{ F.}$$
$$n^\circ \text{ R.} = (\tfrac{9}{4}\,n+32)^\circ \text{ F.} = \tfrac{5}{4}\,n^\circ \text{ C.}$$
$$= (2\cdot 25\,n+32)^\circ \text{ F.} = 1\cdot 25\,n^\circ \text{ C.}$$

To convert a given temperature on the Fahrenheit scale to degrees Centigrade, subtract 32 and multiply by $\frac{5}{9}$, when the answer will be the required temperature on the Centigrade scale. The following is an example:—

$$173^\circ \text{ Fahr.} = 173 - 32 \times \tfrac{5}{9} = 78{\cdot}33^\circ \text{ C.}$$

To convert a given temperature on the Centigrade scale to the Fahrenheit, multiply by $\frac{9}{5}$ and add 32. The following is an example:—

$$60^\circ \text{ C.} = 60 \times \tfrac{9}{5} + 32 = 140^\circ \text{ Fahr.}$$

The space between boiling point and freezing in Réaumur is divided into 80, in the Centigrade or Celsius into 100, and in the Fahrenheit into 180 equal divisions. The boiling point is respectively indicated by 80°, 100°, and 212°, and the freezing point by 0°, 0° and 32°. On the Fahrenheit scale under the freezing point there are 32 degrees.

Tables II. and III. are arranged for the correction of the specific

gravity of milk and skim-milk (observed at temperatures from 0° and 30° C.), to 15° C. All comparisons are made at that temperature, for the sake of simplicity in practice. When the specific gravity of milk is stated, the first two figures, along with the point, are removed. Thus, for example, a sample of milk having a specific gravity of 1·03175 at 15° C., is spoken of as having a specific gravity of 31·75.

For example, if the specific gravity of milk at 24° C. has been found to be 29·70; at 15° C., therefore, it will be 31·2 + ·1 × ·7, equal to 31·9. There is found on Table II. the numbers 31·2 and 32·2 for 29 and 30 respectively, at 24° C. The difference for one degree amounts to 1, for a tenth of a degree ·1, and for seven-tenths ·7.

The specific gravity of milk may be stated in different ways. It may be stated in comparison to distilled water at 15° C., and weighed in air, or it may be stated in comparison with water at 4° C., and weighed in air or water at 4° C., and calculated in vacuum. According to the method of comparison, the numbers will naturally differ. If, for example, the specific gravity of a sample of milk has been determined by the pyknometer at 15° C. and compared *with distilled water at the same temperature, and weighed in air,* and found to be 1·0315, and if it be desired to convert this number into comparison with water at 4° C., taking the density of water at 15° C. at ·99916, then the figure will be found by multiplying 1·0315 by ·99916, that is, 1·03063. The difference amounts to 1·0315 − 1·03063 = ·00087. If it be desired to calculate this in vacuum, it will be found by multiplying 1·0315 into (·99916 − 00119) + ·00119, that is, 1·03060. The figures, then, for specific gravities are as follows:—

Weighed in air and compared with water at			*15° C.,*	*equal to*	*1·03150.*
,,	,,	,,	4° C.,	,,	1·03063.
,,	in vacuum	,,	4° C.,	,,	1·03060.

As it is sufficient for practical and scientific purposes to know the specific gravity to four places of decimals, it will make little difference whether it is calculated to water at 4° C., or whether it is weighed in vacuum or not. On the other hand, it is not the same whether the specific gravity be taken with reference to water at 15° C. or at 4° C. As a rule, the specific gravity of milk is calculated at 15° C., and compared with distilled water at the same temperature.

Table IV A. and IV B. serve for the calculation of total solids (t) when the specific gravity (s) at 15° C. and the percentage of fat (f) are known. Both tables are based on the following formula:—

$$(1)\ t=\frac{n\times 1\cdot 07527-1}{n-1}\times f+\frac{n}{n-1}\times\frac{100\times s-100}{s}.$$

In the above formula (n) equals the specific gravity of the solids not fat at 15° C. This amount, as has already been pointed out, is very nearly constant. It may be worth while to calculate its value in those districts in which the above formula will be used. This can be done by the following formula:—

$$(2)\ n=\frac{s\times s^1(t-f)}{100\times s^1-s\times s^1\ (100-t)-s\times f}$$

in which (s^1) is the specific gravity of the butter-fat at 15° C. compared with water at a similar temperature.

If 1·600734 be taken for the value of (n), as stated in formula (1), the following will be the result. Substituting for the figures $100\times s-100=d$:—

$$(3)\ t=1\cdot 2\times f+2\cdot 665\times\frac{d}{s^1},$$

and from this we obtain the following:—

$$f=\cdot 833\times t-2\cdot 22\times\frac{d}{s^1},$$

and

$$s=\frac{1000}{1000-3\cdot 75\ (t-1\cdot 2\times f)}.$$

If, for example, it had been calculated that $(s)=1\cdot 0321$ and $(f)=3\cdot 456$ per cent, from Table IV A. for $1\cdot 2\times f=4\cdot 147$ per cent, and from Table IV B. $2\cdot 665\times\frac{d}{s}=8\cdot 288$ per cent; therefore $(t)=12\cdot 435$ per cent.

Both tables can be used for the calculation of (f), if (s) and (t) are given, for from equation (3) it follows that

$$f=\frac{t-2\cdot 665\times\frac{d}{s}}{1\cdot 2}.$$

If, therefore, (t) equals 12·435 and (s) 1·0321 from Table IV B., its value would be $2\cdot 665\times\frac{d}{s}=8\cdot 288$. If we take this number from 12·435, the figure 4·147 is found, a number which, by division with 1·2, gives the percentage of fat at 3·456 per cent.

Table V. serves for calculating the specific gravity (m) of the total solids of milk at 15° C., compared with water at like temperature.

In many cases where the question arises as to whether milk has been adulterated or not, as has already been pointed out in § 31, page 69, the value of m can be obtained from the formula,

$$m = \frac{t}{t - \frac{d}{s}};$$

in which (t) equals 12·435 per cent, and (s) equals 1·0321. From Table V. we obtain for $\frac{d}{s} = 3·110$. If one subtracts this number and divides 12·435 by the remainder, 9·325, we obtain (m) equal to 1·333.

Table VI., calculated by J. Nisius, gives the relation of the percentage of fat (p) and specific gravity of the total solids (m) of milk. In order to distinguish among several samples of milk the compositions of those which are known to be comparatively rich in fat, that is, in comparison with the non-fatty solids, the composition of all the samples must be calculated to a similar percentage of total solids. Formerly, in such a comparison, the percentage 12 or 12·5 was generally chosen. It appeared to the author to be more suitable to calculate the percentage of the amount of fat in the dry substance.

(m) can easily be calculated if (p) is given, or (p) if (m) is given.

By the formula

$$m = \frac{2665}{1665 + 12 \times p}$$

the following is obtained:—

$$(1)\ m = \frac{100}{62·48 + ·45 \times p}, \text{ and } (2)\ p = \frac{100}{0·45 \times m} - 138·90.$$

For (p) 27·792 per cent, for example, (m) equals $\frac{100}{75}$ equals 1·334, and where (m) equals 1·334 (p) will be 27·80 per cent.

TABLE I.

Comparison of Fahrenheit and Centigrade Thermometric Scales.

F.	C.	F.	C.	F.	C.	F.	C.	F.	C.
32	0·00	69	20·56	106	41·11	143	61·67	180	82·22
33	0·56	70	21·11	107	41·67	144	62·22	181	82·78
34	1·11	71	21·67	108	42·22	145	62·78	182	83·33
35	1·67	72	22·22	109	42·78	146	63·33	183	83·89
36	2·22	73	22·78	110	43·33	147	63·89	184	84·44
37	2·78	74	23·33	111	43·89	148	64·44	185	85·00
38	3·33	75	23·89	112	44·44	149	65·00	186	85·56
39	3·89	76	24·44	113	45·00	150	65·56	187	86·11
40	4·44	77	25·00	114	45·56	151	66·11	188	86·67
41	5·00	78	25·56	115	46·11	152	66·67	189	87·22
42	5·56	79	26·11	116	46·67	153	67·22	190	87·78
43	6·11	80	26·67	117	47·22	154	67·78	191	88·33
44	6·67	81	27·22	118	47·78	155	68·33	192	88·89
45	7·22	82	27·78	119	48·33	156	68·89	193	89·44
46	7·78	83	28·33	120	48·89	157	69·44	194	90·00
47	8·33	84	28·89	121	49·44	158	70·00	195	90·56
48	8·89	85	29·44	122	50·00	159	70·56	196	91·11
49	9·44	86	30·00	123	50·56	160	71·11	197	91·67
50	10·00	87	30·56	124	51·11	161	71·67	198	92·22
51	10·56	88	31·11	125	51·67	162	72·22	199	92·78
52	11·11	89	31·67	126	52·22	163	72·78	200	93·33
53	11·67	90	32·22	127	52·78	164	73·33	201	93·89
54	12·22	91	32·78	128	53·33	165	73·89	202	94·44
55	12·78	92	33·33	129	53·89	166	74·44	203	95·00
56	13·33	93	33·89	130	54·44	167	75·00	204	95·56
57	13·89	94	34·44	131	55·00	168	75·56	205	96·11
58	14·44	95	35·00	132	55·56	169	76·11	206	96·67
59	15·00	96	35·56	133	56·11	170	76·67	207	97·22
60	15·56	97	36·11	134	56·67	171	77·22	208	97·73
61	16·11	98	36·67	135	57·22	172	77·78	209	98·33
62	16·67	99	37·22	136	57·78	173	78·33	210	98·89
63	17·22	100	37·78	137	58·33	174	78·89	211	99·44
64	17·78	101	38·33	138	58·89	175	79·44	212	100·00
65	18·33	102	38·89	139	59·44	176	80·00		
66	18·89	103	39·44	140	60·00	177	80·56		
67	19·44	104	40·00	141	60·56	178	81·11		
68	20·00	105	40·56	142	61·11	179	81·67		

TABLE II.

Correction of Specific Gravity of Milk observed at temperatures between 0° C. and 30° C. to 15° C.

°C.	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	°C.
0	12·9	13·9	14·9	15·9	16·9	17·8	18·7	19·6	20·6	21·5	22·4	23·3	24·3	25·2	26·1	27·0	27·9	28·8	29·7	30·6	31·5	32·4	0
1	12·9	13·9	14·9	15·9	16·9	17·8	18·7	19·6	20·6	21·5	22·4	23·3	24·3	25·3	26·2	27·1	28·0	28·9	29·8	30·7	31·6	32·5	1
2	12·9	13·9	14·9	15·9	16·9	17·8	18·7	19·7	20·7	21·6	22·5	23·4	24·4	25·4	26·3	27·2	28·1	29·0	29·9	30·8	31·7	32·6	2
3	13·0	14·0	15·0	16·0	17·0	17·9	18·8	19·7	20·7	21·7	22·6	23·5	24·5	25·5	26·4	27·3	28·2	29·1	30·0	30·9	31·8	32·7	3
4	13·0	14·0	15·0	16·0	17·0	17·9	18·8	19·7	20·7	21·7	22·7	23·6	24·6	25·6	26·5	27·4	28·3	29·2	30·1	31·0	31·9	32·8	4
5	13·1	14·1	15·1	16·1	17·1	18·0	18·9	19·8	20·8	21·8	22·8	23·7	24·7	25·7	26·6	27·5	28·4	29·3	30·3	31·1	32·1	33·0	5
6	13·1	14·1	15·1	16·1	17·1	18·1	19·0	19·9	20·9	21·9	22·9	23·8	24·8	25·8	26·7	27·6	28·5	29·5	30·4	31·3	32·2	33·1	6
7	13·1	14·1	15·1	16·1	17·1	18·1	19·0	20·0	21·0	22·0	23·0	23·9	24·9	25·9	26·8	27·7	28·6	29·6	30·5	31·4	32·3	33·2	7
8	13·2	14·2	15·2	16·2	17·2	18·2	19·1	20·1	21·1	22·1	23·1	24·0	25·0	26·0	26·9	27·8	28·7	29·7	30·6	31·6	32·5	33·4	8
9	13·3	14·3	15·3	16·3	17·3	18·3	19·2	20·2	21·2	22·2	23·2	24·1	25·1	26·1	27·0	27·9	28·8	29·8	30·8	31·8	32·7	33·6	9
10	13·4	14·4	15·4	16·4	17·4	18·4	19·3	20·3	21·3	22·3	23·3	24·2	25·2	26·2	27·1	28·1	29·0	30·0	31·0	32·0	32·9	33·8	10
11	13·5	14·5	15·5	16·5	17·5	18·5	19·4	20·4	21·4	22·4	23·4	24·3	25·3	26·3	27·2	28·2	29·2	30·2	31·2	32·2	33·1	34·0	11
12	13·6	14·6	15·6	16·6	17·6	18·6	19·5	20·5	21·5	22·5	23·5	24·5	25·5	26·5	27·4	28·4	29·4	30·4	31·4	32·4	33·3	34·2	12
13	13·7	14·7	15·7	16·7	17·7	18·7	19·6	20·6	21·6	22·6	23·6	24·6	25·6	26·6	27·6	28·6	29·6	30·6	31·6	32·6	33·5	34·4	13
14	13·8	14·8	15·8	16·8	17·8	18·8	19·8	20·8	21·8	22·8	23·8	24·8	25·8	26·8	27·8	28·8	29·8	30·8	31·8	32·8	33·8	34·7	14
15	14·0	15·0	16·0	17·0	18·0	19·0	20·0	21·0	22·0	23·0	24·0	25·0	26·0	27·0	28·0	29·0	30·0	31·0	32·0	33·0	34·0	35·0	15
16	14·1	15·1	16·1	17·1	18·1	19·1	20·1	21·1	22·2	23·2	24·2	25·2	26·2	27·2	28·2	29·2	30·2	31·2	32·2	33·2	34·2	35·2	16
17	14·2	15·2	16·3	17·3	18·3	19·3	20·3	21·4	22·4	23·4	24·4	25·4	26·4	27·4	28·4	29·4	30·4	31·4	32·4	33·4	34·4	35·4	17
18	14·4	15·4	16·5	17·5	18·5	19·5	20·5	21·6	22·6	23·6	24·6	25·6	26·6	27·6	28·6	29·6	30·6	31·7	32·7	33·7	34·7	35·7	18
19	14·6	15·6	16·7	17·7	18·7	19·7	20·7	21·8	22·8	23·8	24·8	25·8	26·9	27·9	28·9	29·9	30·9	32·0	33·0	34·0	35·0	36·0	19
20	14·8	15·8	16·9	17·9	18·9	19·9	20·9	22·0	23·0	24·0	25·0	26·0	27·1	28·2	29·2	30·2	31·2	32·3	33·3	34·3	35·3	36·3	20
21	15·0	16·0	17·1	18·1	19·1	20·1	21·1	22·2	23·2	24·2	25·2	26·2	27·3	28·4	29·4	30·4	31·4	32·5	33·6	34·6	35·6	36·6	21
22	15·2	16·2	17·3	18·3	19·3	20·3	21·3	22·4	23·4	24·4	25·4	26·4	27·5	28·6	29·6	30·6	31·6	32·7	33·8	34·9	35·9	36·9	22
23	15·4	16·4	17·5	18·5	19·5	20·5	21·5	22·6	23·6	24·6	25·6	26·6	27·7	28·8	29·9	30·9	31·9	33·0	34·1	35·2	36·2	37·2	23
24	15·6	16·6	17·7	18·7	19·7	20·7	21·7	22·8	23·8	24·8	25·8	26·8	27·9	29·0	30·1	31·2	32·2	33·3	34·4	35·5	36·5	37·5	24
25	15·8	16·8	17·9	18·9	19·9	20·9	21·9	23·0	24·1	25·1	26·1	27·1	28·2	29·3	30·4	31·5	32·5	33·6	34·7	35·8	36·8	37·8	25
26	16·0	17·0	18·1	19·1	20·1	21·1	22·1	23·2	24·3	25·3	26·3	27·3	28·4	29·5	30·6	31·7	32·7	33·8	34·9	36·0	37·1	38·1	26
27	16·2	17·2	18·3	19·3	20·3	21·3	22·3	23·4	24·5	25·5	26·5	27·5	28·6	29·7	30·8	31·9	33·0	34·1	35·2	36·3	37·4	38·4	27
28	16·4	17·4	18·5	19·5	20·5	21·5	22·5	23·6	24·7	25·7	26·7	27·7	28·9	30·0	31·1	32·2	33·3	34·4	35·5	36·6	37·7	38·7	28
29	16·6	17·6	18·7	19·7	20·7	21·7	22·7	23·8	24·9	26·0	27·0	28·0	29·2	30·3	31·4	32·5	33·6	34·7	35·8	36·9	38·0	39·1	29
30	16·8	17·8	18·9	20·0	21·0	22·0	23·0	24·1	25·2	26·3	27·3	28·3	29·5	30·6	31·7	32·8	33·9	35·1	36·2	37·3	38·4	39·5	30

Directions for Use.—Suppose the specific gravity found at 18° C., to be 1·030, this is represented in the Table, on the horizontal line at the top, by the last two figures, viz. 30. Under the figure 30, the number corresponding to the temperature 18° C. (in the vertical column at the sides of the table) is found, which in this case is 30·6, and represents the specific gravity at 15° C.

TABLE III.

Correction of Specific Gravity of Skim-milk observed at temperatures between 0° C. and 30° C. to 15° C.

°C.	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	°C.
0	17·2	18·2	19·2	20·2	21·1	22·0	22·9	23·8	24·8	25·8	26·8	27·8	28·7	29·7	30·7	31·7	32·6	33·5	34·4	35·3	36·2	37·1	38·0	0
1	17·2	18·2	19·2	20·2	21·1	22·0	22·9	23·8	24·8	25·8	26·8	27·8	28·7	29·7	30·7	31·7	32·6	33·5	34·4	35·4	36·3	37·2	38·1	1
2	17·2	18·2	19·2	20·2	21·1	22·0	22·9	23·8	24·8	25·8	26·8	27·8	28·7	29·7	30·7	31·7	32·6	33·5	34·5	35·5	36·4	37·3	38·2	2
3	17·2	18·2	19·2	20·2	21·1	22·0	22·9	23·8	24·8	25·8	26·8	27·8	28·7	29·7	30·7	31·7	32·7	33·6	34·6	35·6	36·5	37·4	38·3	3
4	17·2	18·2	19·2	20·2	21·2	22·1	23·0	23·9	24·9	25·9	26·9	27·9	28·8	29·8	30·8	31·8	32·8	33·7	34·7	35·7	36·6	37·5	38·4	4
5	17·3	18·3	19·3	20·3	21·3	22·2	23·1	24·0	25·0	26·0	27·0	28·0	28·9	29·9	30·9	31·9	32·9	33·8	34·8	35·8	36·7	37·6	38·5	5
6	17·3	18·3	19·3	20·3	21·3	22·3	23·2	24·1	25·1	26·1	27·1	28·1	29·0	30·0	31·0	32·0	32·9	33·8	34·8	35·8	36·8	37·7	38·6	6
7	17·3	18·3	19·3	20·3	21·3	22·3	23·2	24·1	25·1	26·1	27·1	28·1	29·0	30·0	31·0	32·0	33·0	33·9	34·9	35·9	36·9	37·8	38·7	7
8	17·3	18·3	19·3	20·3	21·3	22·3	23·2	24·1	25·1	26·1	27·1	28·1	29·1	30·1	31·1	32·1	33·1	34·0	35·0	36·0	37·0	37·9	38·8	8
9	17·4	18·4	19·4	20·4	21·4	22·4	23·3	24·2	25·2	26·2	27·2	28·2	29·2	30·2	31·2	32·2	33·2	34·1	35·1	36·1	37·1	38·0	38·9	9
10	17·5	18·5	19·5	20·5	21·5	22·5	23·4	24·3	25·3	26·3	27·3	28·3	29·3	30·3	31·3	32·3	33·3	34·2	35·2	36·2	37·2	38·2	39·1	10
11	17·6	18·6	19·6	20·6	21·6	22·6	23·5	24·4	25·4	26·4	27·4	28·4	29·4	30·4	31·4	32·4	33·4	34·3	35·3	36·3	37·3	38·3	39·2	11
12	17·7	18·7	19·7	20·7	21·7	22·7	23·6	24·5	25·5	26·5	27·5	28·5	29·5	30·5	31·5	32·5	33·5	34·4	35·4	36·4	37·4	38·4	39·4	12
13	17·8	18·8	19·8	20·8	21·8	22·8	23·7	24·6	25·6	26·6	27·6	28·6	29·6	30·6	31·6	32·6	33·6	34·6	35·6	36·6	37·6	38·6	39·6	13
14	17·9	18·9	19·9	20·9	21·9	22·9	23·8	24·8	25·8	26·8	27·8	28·8	29·8	30·8	31·8	32·8	33·8	34·8	35·8	36·8	37·8	38·8	39·8	14
15	18·0	19·0	20·0	21·0	22·0	23·0	24·0	25·0	26·0	27·0	28·0	29·0	30·0	31·0	32·0	33·0	34·0	35·0	36·0	37·0	38·0	39·0	40·0	15
16	18·1	19·1	20·1	21·1	22·1	23·1	24·1	25·1	26·1	27·1	28·1	29·1	30·1	31·2	32·2	33·2	34·2	35·2	36·2	37·2	38·2	39·2	40·2	16
17	18·2	19·2	20·2	21·2	22·2	23·2	24·2	25·2	26·3	27·3	28·3	29·3	30·3	31·4	32·4	33·4	34·4	35·4	36·4	37·4	38·4	39·4	40·4	17
18	18·4	19·4	20·4	21·4	22·4	23·4	24·4	25·4	26·5	27·5	28·5	29·5	30·5	31·6	32·6	33·6	34·6	35·6	36·6	37·6	38·6	39·6	40·6	18
19	18·6	19·6	20·6	21·6	22·6	23·6	24·6	25·6	26·7	27·7	28·7	29·7	30·7	31·8	32·8	33·8	34·8	35·8	36·9	37·9	38·9	39·9	40·9	19
20	18·8	19·8	20·8	21·8	22·8	23·8	24·8	25·8	26·9	27·9	28·9	29·9	30·9	32·0	33·0	34·0	35·0	36·0	37·1	38·2	39·2	40·2	41·2	20
21	18·9	19·9	20·9	21·9	22·9	23·9	24·9	25·9	27·0	28·1	29·1	30·1	31·1	32·2	33·2	34·2	35·2	36·2	37·3	38·4	39·4	40·4	41·4	21
22	19·1	20·1	21·1	22·1	23·1	24·1	25·1	26·1	27·2	28·3	29·3	30·3	31·3	32·4	33·4	34·4	35·4	36·4	37·5	38·6	39·7	40·7	41·7	22
23	19·3	20·3	21·3	22·3	23·3	24·3	25·3	26·3	27·4	28·5	29·5	30·5	31·5	32·6	33·6	34·6	35·6	36·6	37·7	38·8	39·9	41·0	42·0	23
24	19·5	20·5	21·5	22·5	23·5	24·5	25·5	26·5	27·6	28·7	29·7	30·7	31·7	32·8	33·9	34·9	35·9	36·9	38·0	39·1	40·2	41·3	42·3	24
25	19·7	20·7	21·7	22·7	23·7	24·7	25·7	26·7	27·8	28·9	29·9	30·9	31·9	33·0	34·1	35·2	36·2	37·2	38·3	39·4	40·5	41·6	42·6	25
26	19·9	20·9	21·9	22·9	23·9	24·9	25·9	26·9	28·0	29·1	30·1	31·1	32·1	33·2	34·3	35·4	36·4	37·4	38·5	39·6	40·7	41·8	42·9	26
27	20·1	21·1	22·1	23·1	24·1	25·1	26·1	27·1	28·2	29·3	30·3	31·3	32·3	33·4	34·5	35·6	36·7	37·7	38·8	39·9	41·0	42·1	43·2	27
28	20·3	21·3	22·3	23·3	24·3	25·3	26·3	27·3	28·4	29·5	30·5	31·5	32·5	33·6	34·7	35·8	36·9	38·0	39·1	40·2	41·3	42·4	43·5	28
29	20·5	21·5	22·5	23·5	24·5	25·5	26·5	27·5	28·6	29·7	30·7	31·7	32·7	33·9	35·0	36·1	37·2	38·3	39·4	40·5	41·6	42·7	43·8	29
30	20·7	21·7	22·7	23·7	24·7	25·7	26·7	27·7	28·8	29·9	31·0	32·0	33·0	34·1	35·2	36·3	37·4	38·5	39·7	40·8	41·9	43·0	44·1	30

For explanation of the use of this Table see Table II.

TABLE IVA.

For Calculating the Total Solids **t**, *from the Specific Gravity* **s**, *and the percentage of Fat* **f**.

For the calculation of **t**. To be used in conjunction with Table IVB.

f	$1{\cdot}2 \times f$	f	$1{\cdot}2 \times f$	f	$1{\cdot}2 \times f$	f	$1{\cdot}2 \times f$	f	$1{\cdot}2 \times f$
1·00	1·200	**1·50**	1·800	**2·00**	2·400	**2·50**	3·000	**3·00**	3·600
01	1·212	51	1·812	01	2·412	51	3·012	01	3·612
02	1·224	52	1·824	02	2·424	52	3·024	02	3·624
03	1·236	53	1·836	03	2·436	53	3·036	03	3·636
04	1·248	54	1·848	04	2·448	54	3·048	04	3·648
05	1·260	55	1·860	05	2·460	55	3·060	05	3·660
06	1·272	56	1·872	06	2·472	56	3·072	06	3·672
07	1·284	57	1·884	07	3·484	57	3·084	07	3·684
08	1·296	58	1·896	08	2·496	58	3·096	08	3·696
09	1·308	59	1·908	09	2·508	59	3·108	09	3·708
1·10	1·320	**1·60**	1·920	**2·10**	2·520	**2·60**	3·120	**3·10**	3·720
11	1·332	61	1·932	11	2·532	61	3·132	11	3·732
12	1·344	62	1·944	12	2·544	62	3·144	12	3·744
13	1·356	63	1·956	13	2·556	63	3·156	13	3·756
14	1·368	64	1·968	14	2·568	64	3·168	14	3·768
15	1·380	65	1·980	15	2·580	65	3·180	15	3·780
16	1·392	66	1·992	16	2·592	66	3·192	16	2·792
17	1·404	67	2·004	17	2·604	67	3·204	17	3·804
18	1·416	68	2·016	18	2·616	68	3·216	18	3·816
19	1·428	69	2·028	19	2·628	69	3·228	19	3·828
1·20	1·440	**1·70**	2·040	**2·20**	2·640	**2·70**	3·240	**3·20**	3·840
21	1·452	71	2·052	21	2·652	71	3·252	21	3·852
22	1·464	72	2·064	22	2·664	72	3·264	22	3·864
23	1·476	73	2·076	23	2·676	73	3·276	23	3·876
24	1·488	74	2·088	24	2·688	74	3·288	24	3·888
25	1·500	75	2·100	25	2·700	75	3·300	25	3·900
26	1·512	76	2·112	26	2·712	76	3·312	26	3·912
27	1·524	77	2·124	27	2·724	77	3·324	27	3·924
28	1·536	78	2·136	28	2·736	78	3·336	28	3·936
29	1·548	79	2·148	29	2·748	79	3·348	29	3·948
1·30	1·560	**1·80**	2·160	**2·30**	2·760	**2·80**	3·360	**3·30**	3·960
31	1·572	81	2·172	31	2·772	81	3·372	31	3·972
32	1·584	82	2·184	32	2·784	82	3·384	32	3·984
33	1·596	83	2·196	33	2·796	83	3·396	33	3·996
34	1·608	84	2·208	34	2·808	84	3·408	34	4·008
35	1·620	85	2·220	35	2·820	85	3·420	35	4·020
36	1·632	86	2·232	36	2·832	86	3·432	36	4·032
37	1·644	87	2·244	37	2·844	87	3·444	37	4·044
38	1·656	88	2·256	38	2·856	88	3·456	38	4·056
39	1·668	89	2·268	39	2·868	89	3·468	39	4·068
1·40	1·680	**1·90**	2·280	**2·40**	2·880	**2·90**	3·480	**3·40**	4·080
41	1·692	91	2·292	41	2·892	91	3·492	41	4·092
42	1·704	92	2·304	42	2·904	92	3·504	42	4·104
43	1·716	93	2·316	43	2·916	93	3·516	43	4·116
44	1·728	94	2·328	44	2·928	94	3·528	44	4·128
45	1·740	95	2·340	45	2·940	95	3·540	45	4·140
46	1·752	96	2·352	46	2·952	96	3·552	46	4·152
47	1·764	97	2·364	47	2·964	97	3·564	47	4·164
48	1·776	98	2·376	48	2·976	98	3·576	48	4·176
49	1·788	99	2·388	49	2·988	99	3·588	49	4·188
1·50	1·800	**2·00**	2·400	**2·50**	3·000	**3·00**	3·600	**3·50**	4·200

For thousandths of f add,	
9	0·011
8	0·010
7	0·008
6	0·007
5	0·006
4	0·005
3	0·004
2	0·002
1	0·001

TABLE IV A.—(*Continued*).

f	$1·2 \times f$	f	$1·2 \times f$	f	$1·2 \times f$	f	$1·2 \times f$	f	$1·2 \times f$
3·50	4·200	**4·00**	4·800	**4·50**	5·400	**5·00**	6·000	**5·50**	6·600
[illegible]	4·212	01	4·812	51	5·412	01	6·012	51	6·612
52	4·224	02	4·824	52	5·424	02	6·024	52	6·624
53	4·236	03	4·836	53	5·436	03	6·036	53	6·636
54	4·248	04	4·848	54	5·448	04	6·048	54	6·648
55	4·260	05	4·860	55	5·460	05	6·060	55	6·660
56	4·272	06	4·872	56	5·472	06	6·072	56	6·672
57	4·284	07	4·884	57	5·484	07	6·084	57	6·684
58	4·296	08	4·896	58	5·496	08	6·096	58	6·696
59	4·308	09	4·908	59	5·508	09	6·108	59	6·708
3·60	4·320	**4·10**	4·920	**4·60**	5·520	**5·10**	6·120	**5·60**	6·720
61	4·332	11	4·932	61	5·532	11	6·132	61	6·732
62	4·344	12	4·944	62	5·544	12	6·144	62	6·744
63	4·356	13	4·956	63	5·556	13	6·156	63	6·756
64	4·368	14	4·968	64	5·568	14	6·168	64	6·768
65	4·380	15	4·980	65	5·580	15	6·180	65	6·780
66	4·392	16	4·992	66	5·592	16	6·192	66	6·792
67	4·404	17	5·004	67	5·604	17	6·204	67	6·804
68	4·416	18	5·016	68	5·616	18	6·216	68	6·816
69	4·428	19	5·028	69	5·628	19	6·228	69	6·828
3·70	4·440	**4·20**	5·040	**4·70**	5·640	**5·20**	6·240	**5·70**	6·840
71	4·452	21	5·052	71	5·652	21	6·252	71	6·852
72	4·464	22	5·064	72	5·664	22	6·264	72	6·864
73	4·476	23	5·076	73	5·676	23	6·276	73	6·876
74	4·488	24	5·088	74	5·688	24	6·288	74	6·888
75	4·500	25	5·100	75	5·700	25	6·300	75	6·900
76	4·512	26	5·112	76	5·712	26	6·312	76	6·912
77	4·524	27	5·124	77	5·724	27	6·324	77	6·924
78	4·536	28	5·136	78	5·736	28	6·336	78	6·936
79	4·548	29	5·148	79	5·748	29	6·348	79	6·948
3·80	4·560	**4·30**	5·160	**4·80**	5·760	**5·30**	6·360	**5·80**	6·960
81	4·572	31	5·172	81	5·772	31	6·372	81	6·972
82	4·584	32	5·184	82	5·784	32	6·384	82	6·984
83	4·596	33	5·196	83	5·796	33	6·396	83	6·996
84	4·608	34	5·208	84	5·808	34	6·408	84	7·008
85	4·620	35	5·220	85	5·820	35	6·420	85	7·020
86	4·632	36	5·232	86	5·832	36	6·432	86	7·032
87	4·644	37	5·244	87	5·844	37	6·444	87	7·044
88	4·656	38	5·256	88	5·856	38	6·456	88	7·056
89	4·668	39	5·268	89	5·868	39	6·468	89	7·068
3·90	4·680	**4·40**	5·280	**4·90**	5·880	**5·40**	6·480	**5·90**	7·080
91	4·692	41	5·292	91	5·892	41	6·492	91	7·092
92	4·704	42	5·304	92	5·904	42	6·504	92	7·104
93	4·716	43	5·316	93	5·916	43	6·516	93	7·116
94	4·728	44	5·328	94	5·928	44	6·528	94	7·128
95	4·740	45	5·340	95	5·940	45	6·540	95	7·140
96	4·752	46	5·352	96	5·952	46	6·552	96	7·152
97	4·764	47	5·364	97	5·964	47	6·564	97	7·164
98	4·776	48	5·376	98	5·976	48	6·576	98	7·176
99	4·788	49	5·388	99	5·988	49	6·588	99	7·188
4·00	4·800	**4·50**	5·400	**5·00**	6·000	**5·50**	6·600	**6·00**	7·200

For thousandths of f	add, ...
9	0·011
8	0·010
7	0·008
6	0·007
5	0·006
4	0·005
3	0·004
2	0·002
1	0·001

DIRECTIONS FOR USE.—If the fat (f) is found on analysis to be 3·45 per cent, then the column under f is examined till the number 3·45 is found, and its equivalent in the column headed $1·2 \times f$ is noted. This is found in this case to be 4·14. This amount, added to the result found from Table IV B. (for the use of which see the accompanying directions), gives the percentage of total solids.

TABLE IV B.

For Calculating the Total Solids **t**, *from the Specific Gravity* **s**, *and the percentage of Fat* **f**.

For the calculation of **t**. To be used in conjunction with Table IV A.

s. Thousandths	$2{\cdot}665 \times \frac{d}{s}$	*s*. Thousandths	$2{\cdot}665 \times \frac{d}{s}$	*s*. Thousandths	$2{\cdot}665 \times \frac{d}{s}$	*s*. Thousandths	$2{\cdot}665 \times \frac{d}{s}$	*s*. Thousandths	$2{\cdot}665 \times \frac{d}{s}$
19·0	4·967	**24·0**	6·246	**29·0**	7·511	**34·0**	8·763	**39·0**	10·003
1	4·994	1	6·271	1	7·536	1	8·788	1	10·028
2	5·021	2	6·297	2	7·561	2	8·813	2	10·053
3	5·047	3	6·322	3	7·586	3	8·838	3	10·077
4	5·072	4	6·348	4	7·611	4	8·863	4	10·102
5	5·098	5	6·373	5	7·636	5	8·888	5	10·127
6	5·122	6	6·398	6	7·662	6	8·912	6	10·151
7	5·149	7	6·424	7	7·687	7	8·937	7	10·176
8	5·173	8	6·449	8	7·712	8	8·962	8	10·201
9	5·199	9	6·475	9	7·737	9	8·987	9	10·225
20·0	5·225	**25·0**	6·500	**30·0**	7·762	**35·0**	9·012	**40·0**	10·250
1	5·251	1	6·525	1	7·787	1	9·037		
2	5·277	2	6·551	2	7·812	2	9·062		
3	5·302	3	6·576	3	7·837	3	9·087		
4	5·328	4	6·601	4	7·863	4	9·111		
5	5·353	5	6·627	5	7·888	5	9·136		
6	5·379	6	6·652	6	7·913	6	9·161		
7	5·405	7	6·677	7	7·938	7	9·186		
8	5·430	8	6·703	8	7·963	8	9·211		
9	5·456	9	6·728	9	7·988	9	9·236		
21·0	5·481	**26·0**	6·753	**31·0**	8·013	**36·0**	9·261		
1	5·507	1	6·779	1	8·038	1	9·285		
2	5·532	2	6·804	2	8·063	2	9·310		
3	5·558	3	6·829	3	8·088	3	9·335		
4	5·584	4	6·855	4	8·113	4	9·360		
5	5·609	5	6·880	5	8·138	5	9·385		
6	5·635	6	6·905	6	8·163	6	9·409		
7	5·660	7	6·930	7	8·188	7	9·434		
8	5·686	8	6·956	8	8·213	8	9·459		
9	5·711	9	6·981	9	8·239	9	9·484		
22·0	5·737	**27·0**	7·006	**32·0**	8·264	**37·0**	9·509		
1	5·762	1	7·032	1	8·289	1	9·533		
2	5·788	2	7·057	2	8·314	2	9·558		
3	5·813	3	7·082	3	8·339	3	9·583		
4	5·839	4	7·107	4	8·364	4	9·608		
5	5·864	5	7·133	5	8·389	5	9·632		
6	5·890	6	7·158	6	8·414	6	9·657		
7	5·915	7	7·183	7	8·439	7	9·682		
8	5·941	8	7·208	8	8·464	8	9·707		
9	5·966	9	7·234	9	8·489	9	9·732		
23·0	5·992	**28·0**	7·259	**33·0**	8·514	**38·0**	9·756		
1	6·017	1	7·284	1	8·539	1	9·781		
2	6·042	2	7·309	2	8·563	2	9·806		
3	6·068	3	7·334	3	8·588	3	9·830		
4	6·093	4	7·360	4	8·613	4	9·855		
5	6·119	5	7·385	5	8·638	5	9·880		
6	6·144	6	7·410	6	8·663	6	9·904		
7	6·170	7	7·435	7	8·688	7	9·929		
8	6·195	8	7·460	8	8·713	8	9·954		
9	6·221	9	7·485	9	8·738	9	9·979		
24·0	6·246	**29·0**	7·511	**34·0**	8·763	**39·0**	10·003		

DIRECTIONS FOR USE.—If the specific gravity (*s*) is ascertained to be 1·032 at 15° C.—and this is represented in the Table by the *last two figures*, *viz.* 32—the column headed $2{\cdot}665 \times \frac{d}{s}$ *is examined*, and the number corresponding to 32 found, which in this case is 8·264. This, added to the number found in Table IV. B., gives the percentage of total solids.

TABLE V.

For calculating Specific Gravity of the Total Solids of Milk **m**, *from the Specific Gravity* **s**, *and the percentage of Total Solids* **t**.

s Thousandths	d/s	s Thousandths	d/s	s Thousandths	d/s	s Thousandths	d/s	s Thousandths	d/s
19·0	1·864	**24·0**	2·344	**29·0**	2·818	**34·0**	3·288	**39·0**	3·754
1	1·874	1	2·353	1	2·828	1	3·298	1	3·763
2	1·884	2	2·363	2	2·837	2	3·307	2	3·772
3	1·894	3	2·372	3	2·847	3	3·316	3	3·781
4	1·903	4	2·382	4	2·856	4	3·326	4	3·791
5	1·913	5	2·391	5	2·865	5	3·335	5	3·800
6	1·922	6	2·401	6	2·875	6	3·344	6	3·809
7	1·932	7	2·410	7	2·884	7	3·354	7	3·818
8	1·941	8	2·420	8	2·894	8	3·363	8	3·828
9	1·951	9	2·429	9	2·903	9	3·372	9	3·837
20·0	1·961	**25·0**	2·439	**30·0**	2·913	**35·0**	3·382	**40·0**	3·846
1	1·970	1	2·449	1	2·922	1	3·391		
2	1·980	2	2·458	2	2·931	2	3·400		
3	1·990	3	2·468	3	2·941	3	3·410		
4	1·999	4	2·477	4	2·950	4	3·419		
5	2·009	5	2·487	5	2·960	5	3·428		
6	2·018	6	2·496	6	2·969	6	3·438		
7	2·028	7	2·506	7	2·979	7	3·447		
8	2·038	8	2·515	8	2·988	8	3·456		
9	2·047	9	2·525	9	2·997	9	3·466		
21·0	2·057	**26·0**	2·534	**31·0**	3·007	**36·0**	3·475		
1	2·066	1	2·544	1	3·016	1	3·484		
2	2·076	2	2·553	2	3·026	2	3·494		
3	2·086	3	2·563	3	3·035	3	3·503		
4	2·095	4	2·572	4	3·044	4	3·512		
5	2·105	5	2·582	5	3·054	5	3·521		
6	2·114	6	2·591	6	3·063	6	3·531		
7	2·124	7	2·601	7	3·073	7	3·540		
8	2·133	8	2·610	8	3·082	8	3·549		
9	2·143	9	2·620	9	3·091	9	3·559		
22·0	2·153	**27·0**	2·629	**32·0**	3·101	**37·0**	3·568		
1	2·162	1	2·638	1	3·110	1	3·577		
2	2·172	2	2·648	2	3·120	2	3·587		
3	2·181	3	2·657	3	3·129	3	3·596		
4	2·191	4	2·667	4	3·138	4	3·605		
5	2·200	5	2·676	5	3·148	5	3·614		
6	2·210	6	2·686	6	3·157	6	3·624		
7	2·220	7	2·695	7	3·166	7	3·633		
8	2·229	8	2·705	8	3·176	8	3·642		
9	2·239	9	2·714	9	3·185	9	3·652		
23·0	2·248	**28·0**	2·724	**33·0**	3·195	**38·0**	3·661		
1	2·258	1	2·733	1	3·204	1	3·670		
2	2·267	2	2·743	2	3·213	2	3·679		
3	2·277	3	2·752	3	3·223	3	3·689		
4	2·286	4	2·762	4	3·232	4	3·698		
5	2·296	5	2·771	5	3·241	5	3·707		
6	2·306	6	2·780	6	3·251	6	3·717		
7	2·315	7	2·790	7	3·260	7	3·726		
8	2·325	8	2·799	8	3·269	8	3·735		
9	2·334	9	2·809	9	3·279	9	3·744		
24·0	2·344	**29·0**	2·818	**34·0**	3·288	**39·0**	3·754		

DIRECTIONS FOR USE.—If the total solids (t) are 12·435 per cent, and the specific gravity of the milk (s) is 1·0321 (represented by the figures 32·1 in the tables), then it is found that $\frac{d}{s}$ = 3·110. This subtracted from the total solids and the total solids divided by the remainder (viz. 9·325), the specific gravity of the total solids (m) is found to be 1·333.

TABLE VI.

Showing the relation between the percentage of Fat **p**, *and the Specific Gravity of the Total Solids* **m** *of Milk.* *Directions for use, see p.* 30.

p	*m*	*p*	*m*	*p*	*m*	*p*	*m*	*p*	*m*
0	1·601	**10**	1·493	**20**	1·399	**30**	1·316	**40**	1·242
1	1·589	11	1·483	21	1·390	31	1·308	41	1·236
2	1·578	12	1·473	22	1·382	32	1·301	42	1·229
3	1·567	13	1·463	23	1·373	33	1·293	43	1·222
4	1·556	14	1·454	24	1·365	34	1·286	44	1·215
5	1·545	15	1·444	25	1·356	35	1·278	45	1·209
6	1·534	16	1·435	26	1·348	36	1·271	46	1·202
7	1·524	17	1·426	27	1·340	37	1·264	47	1·196
8	1·513	18	1·417	28	1·332	38	1·256	48	1·189
9	1·503	19	1·408	29	1·324	39	1·249	49	1·183
10	1·493	**20**	1·399	**30**	1·316	**40**	1·242	**50**	1·177

COMPARISON OF THE METRICAL WITH THE COMMON MEASURES.

MEASURES OF LENGTH.

	In English Inches.	In English Feet =12 Inches.	In English Yards =3 Feet.	In English Fathoms =6 Feet.	In English Miles =1760 Yards.
Millimeter, ...	0·03937	0·0032809	0·0010936	0·0005468	0·0000006
Centimeter, ...	0·39371	0·0328090	0·0109363	0·0054682	0·0000062
Decimeter, ...	3·93708	0·3280899	0·1093633	0·0546816	0·0000621
Meter, ...	39·37079	3·2808992	1·0936331	0·5468165	0·0006214

1 Inch = 2·539944 Centimeters.
1 Foot = 3·0479449 Decimeters.
1 Yard = 0·91438348 Meter.
1 Mile = 1·6093140 Kilometers.

1 Square Inch = 6·4515669 Square Centimeters.
1 Square Foot = 9·2899683 Square Centimeters.
1 Square Yard = 0·83609715 Square Meter or Centiare.
1 Acre = 0·404671021 Hectare.

MEASURES OF CAPACITY.

	In Cubic Inches.	In Cubic Feet =1728 Cub. Inches.	In Pints =34·65923 Cub. Inches.	In Gallons =8 Pints =277·27384 Cubic Inches.	In Bushels =8 Gallons =2218·19075 Cubic Inches.
Milliliter or cub. centimeter,	0·061027	0·0000353	0·001761	0·00022010	0·000027512
Centiliter or 10 cu. centim.,	0·610271	0·0003532	0·017608	0·00220097	0·000275121
Deciliter or 100 cu. centim.,	6·102705	0·0035317	0·176077	0·02200967	0·002751208
Liter or cubic decimeter, ...	61·027052	0·0353166	1·760773	0·22009668	0·027512085

1 Cubic Inch = 16·3861759 Cubic Centimeters. 1 Cubic Foot = 28·3153119 Cubic Decimeters.
1 Gallon = 4·543457969 Liters.

MEASURES OF WEIGHT.

	In English Grains.	In Troy Ounces =480 Grains.	In Avoirdupois Lbs. =7000 Grains.	In Cwts. =112 Lbs. =784,000 Grains.	In Tons =20 Cwts. =15,680,000 Grains.
Milligram, ...	0·015432	0·000032	0·0000022	0·00000002	0·000000001
Centigram, ...	0·154323	0·000322	0·0000220	0·00000020	0·000000010
Decigram, ...	1·543235	0·003215	0·0002205	0·00000197	0·000000098
Gram, ...	15·432349	0·032151	0·0022046	0·00001968	0·000000984
Decagram, ...	154·323488	0·321507	0·0220462	0·00019684	0·000009842
Hectogram, ...	1543·234880	3·215073	0·2204621	0·00196841	0·000098421
Kilogram, ...	15432·348800	32·150727	2·2046213	0·01968412	0·000984206

1 Grain = 0·06479895 Gram.
1 Troy oz. = 31·103496 Grams.

1 Lb. Avd. = 0·45359265 Kilogr.
1 Cwt. = 50·80237689 Kilogr.

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